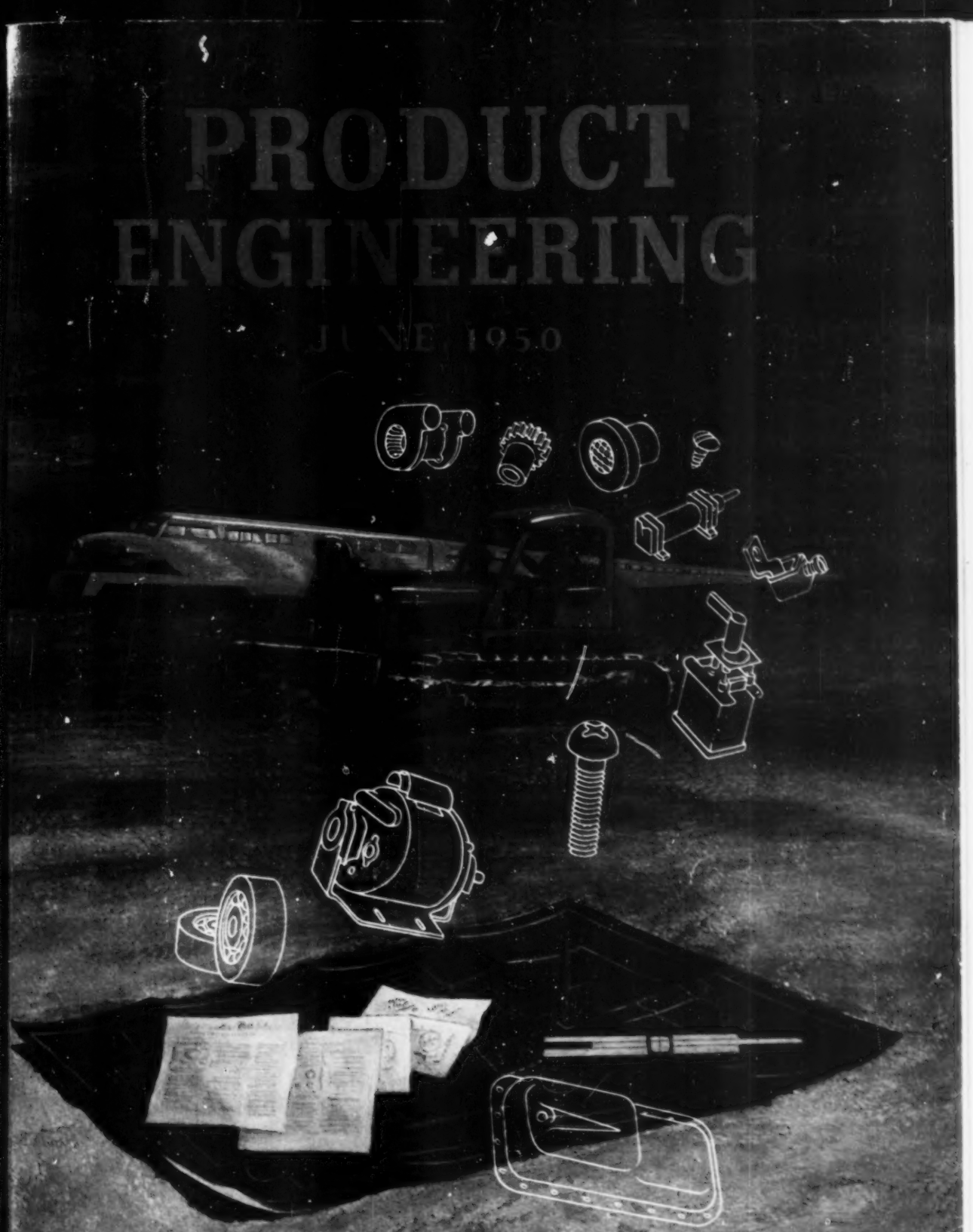
PRODUCT ENGINEERING

JUNE 1950



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Guesses Can Be Highly Expensive

ALTHOUGH THE PERCENTAGE FIGURES MAY VARY considerably among different companies, in every field of machinery and product manufacturing the designer has direct control over a sizeable portion of the total production costs. In the aircraft industry the figure is about 30 percent. According to the breakdown given in a private report on this subject, design specifications and drawings practically determine the costs of 20 percent of the raw material, 25 percent of the components, 40 percent of the shop labor and 30 percent of the tooling costs.

There is nothing startling about the fact that 30 percent of the total manufacturing costs are under the control of the designer. It seems to be common knowledge among both management and engineering executives. Ironically, neither group seems to be much concerned about it. With practically one-third the total manufacturing costs under the control of the engineering design department, one would think that the management would insist that the engineering department be well organized to make cost studies.

Cost analysis is practically non-existent in most engineering departments. Perhaps it is because few managements have enough confidence in the effectiveness of cost analysis. The more usual method for seeking cost reduction is for management to demand lower costs from a production manager and a reduction in the personnel of the engineering design department. The thought of adding a few percent to the cost of operating an engineering department in order to achieve cost reductions in labor, material and tooling is not welcomed by many top managements.

It is regrettable, but most engineering departments are still working in an atmosphere that dates back to almost the dawn of the century. In those days, there were few materials from which to choose and the production processes available were few and simple. With little to choose from, there was little opportunity for the design department to achieve manufacturing economies. Today the picture is entirely different. The engineer might select any one of dozens of different materials for a given application, each material having its own characteristics, workability, and price. Any one of dozens of different manufacturing processes might be employed. A practically unlimited variety of parts and components are obtainable for incorporating into a design. There are boundless opportunities for design modification and simplification to cut total costs.

However, in only relatively few companies do engineers spend much time in analyzing to determine the most economical design commensurate with quality. Usually there is no budget item to cover the expense of operating a cost analysis group. On the other hand, in companies where cost analysis is on an organized basis the returns and savings have been many times the money spent for operating the cost analysis group.

There are a few instances in which cost analysis operations were put on an organized basis but the expected drop in production costs did not materialize. It is not to be expected that results can be achieved over night. Cost data must be accumulated. Often figures on important shop costs must first be established. Progress is slow. But it must be borne in mind that cost decisions based on facts and figures are realistic whereas the decisions of a cost-guessing committee may be very expensive.

G. F. Jordenholt

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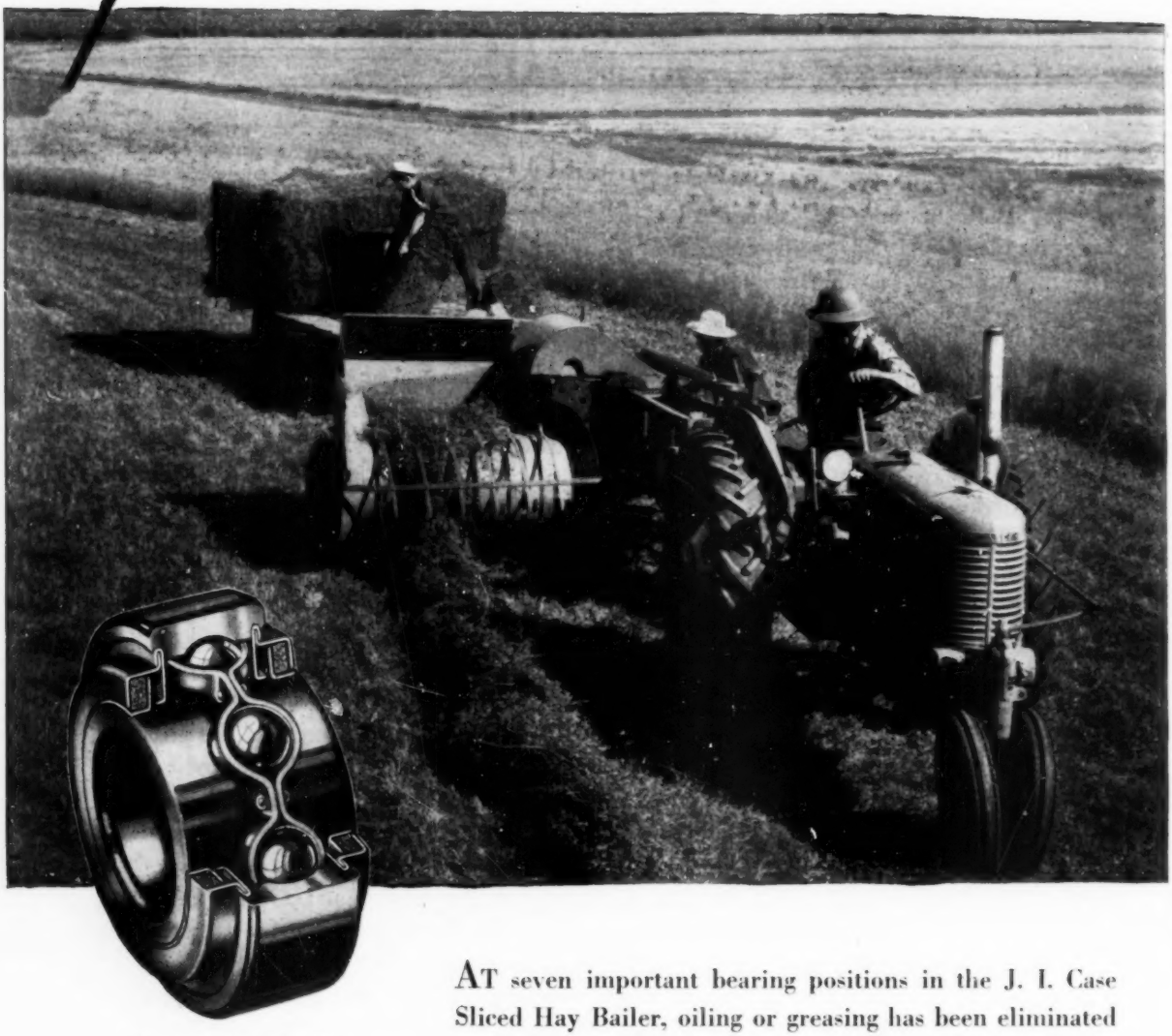

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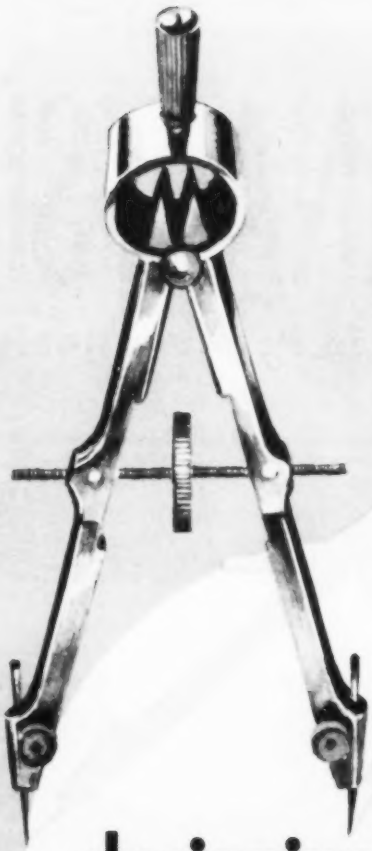


designing with DOLLARS

FEATURE ARTICLES

The Place of Cost Analysis in Product Design
Why Dollar Saving Tipsheets?
The Direct Cost of the Product Must Be Analyzed
Beware of the Cost of Intangibles
About This Problem of Materials Selection

DOLLAR SAVING TIPSHEETS

Mechanical Transmissions • Fasteners • Types of Constructions • Materials • Processes • Hydraulic and Pneumatic Systems • Electrical Devices

A SPECIAL **PRODUCT ENGINEERING** REPORT TO INDUSTRY • JUNE, 1950

The Place of COST ANALYSIS in Product Design

ROBERT H. LUNDBERG

A SUCCESSFUL PRODUCT on today's market is the one with the proper balance between performance and cost. That product must satisfy a particular need, perform a certain function ably and have a certain standard of quality. Possessing those characteristics, it will be a desirable product. But unless the cost of that product is well within the financial means of its potential market, its future is very dim indeed.

The establishment of the standard of performance for a product and its subsequent development has long been accepted as being a function of the engineering department. For years, engineering departments have been accumulating data, procuring and developing specialists to enhance the performance of product design. The control of the article's cost has been left up to the manufacturing division.

It has become increasingly apparent that low manufacturing costs are primarily dependent upon good product design as well as economical production techniques. Therefore, it is only logical that the backbone of any sound product development program must have its inception at the very start of the design program and continue through all phases of engineering as well as manufacturing, tooling and so on.

Unfortunately, most engineering personnel are neither educated nor experienced along formal cost lines. Consequently, many decisions affecting product cost are arbitrarily made during design on the basis of limited experience and opinion if considered at all. If the design is criticized as being the cause of high manufacturing costs, the answer of the engineering department is weak because it is only on an "opinion basis." There are no facts available. There are no figures that can be compared. Engineering may be forced to make some token changes in design which will have little or no effect on the actual cause of the high manufacturing cost. In any event, the outcome of any corrective action is highly uncertain because of a lack of specific data. Such conditions indicate a definite need for analytical cost work being done in conjunction with design.

Many concerns, even those that may be cost conscious, erroneously consider the application of cost studies during design to be a monumental task involving expensive and time-consuming accumulation of data and complex detail work. For that reason the application of cost data by the engineering department is considered to be a task to be done in spare time. Since there is little or no spare time in a well administered organization, specific cost data is so meager that it cannot be used as a sound foundation on which to base design. The only solution to this enigma is a recognition by management of the necessity for a cost analysis group in the engineering department – a group that would be specifically charged with investigating production costs and aiding in the direction of design toward economical production. By such action, establishing a design as being the best from an economy viewpoint becomes a simple matter, redesigns to lower manufacturing costs are reduced to a minimum if not eliminated entirely and absolute preventative cost measures are in effect rather than nebulous corrective actions. It is thus that the proper balance between performance and cost – which a successful product must have – will be put into effect.

Admittedly, there have been many instances in which significant and appreciable cost reductions have been achieved without the assistance of a formal cost analysis group. While this is true, it only emphasizes that the product was improperly designed in the first place. Proper cost analyses applied during design would have detected this feature early and directed the design toward a more economical method. Without cost analysis, comparison of design details, components or parts, or methods that are to be used to produce the product often breaks down into a wrangle between engineers involved in the design. One may have a pet scheme that he would like to try, another has a different proposal, and neither has any facts. The establishment of a formal cost group in the engineering department puts

BOB LUNDBERG has been in the aircraft engineering field now for over nine years, eight and one-half of which were at the Airplane Division of Curtiss-Wright Corporation, where much fundamental work on cost analysis has been done. As a senior product design engineer at this concern, his chief assignment was the development and installation of cost analysis methods, so he knows of what he speaks. Currently, he is associated with the Administrative Engineering Dept. of the Goodyear Aircraft Corp.

the analysis on a sound administrative basis where otherwise it might be a hit or miss operation based on vague memories of experience and on opinions that may be subconsciously prejudiced.

Would Formal Cost Analysis Pay?

While all this sounds good, seems logical, and is in accord with the trend in industry to attempt to produce better products at lower cost, the big question is: "Would it pay?" Would not the salaries of such a group be greater than the savings that might accrue? Would the fact that a cost analysis group existed be any guarantee that lower product costs would be forthcoming? The best answer to that is an actual case history study.

Five years ago, one of the leading manufacturing concerns in the country established a separate engineering group of three engineers to study and specify the least expensive manufacturing methods and to achieve greater design simplicity in their product. Today, this company has achieved highly significant cost savings that total many times the cost of the analysis group. A check of their files reveals some highly interesting case studies. For example:

1) An alternate design which by all opinion and experience was considered to be more economical was proposed to replace an existing design. A complete analysis was made for both designs. Ironically, the analysis proved that the original design was the more economical of the two. By not making the design change, a manufacturing cost saving of more than $12,000 was realized. In addition, weeks of delay were avoided and $2,000 of additional design time was saved.

2) An alternate type of construction and material was recommended for one of the products. During the course of the cost analysis which followed, a number of costly features in the original design were discovered. Correcting the original design accordingly reduced the cost for the first lot of parts by approximately $500.00. Production of the final improved design proved to be more than $3,000 cheaper than the proposed change.

3) Three different designs were proposed for a tank detail. Two of the designs had certain functional advantages, but when costs were analyzed in detail the third design was found to be over $600 cheaper. Because the functional advantage was not worth the cost difference involved, the third design was adopted. The designer, being able to evaluate cost and function on a factual basis, was able to properly balance performance versus cost.

4) In the preliminary studies of a design structure it was discovered that functionally either extruded sections or fabricated sheet metal sections could be used. Cost analysis showed a savings of more than $36,000 if extrusions were used for certain of the structural members. However, it was also found that certain of the other structural members were $30,000 less expensive when fabricated from sheet rather than using extruded section. This is an extremely striking example of the fact that cost decisions cannot be made with any degree of certainty on the broad basis of "past experience and opinion."

5) Generally it is considered that if only a few pieces are involved it is far more economical to sculpture the parts out of the billet stock rather than making forgings. For this reason a number of fittings on a structure were designed as parts to be machined from billet stock, there being only two structures to be built. However, a cost analysis showed that by judicious redesign the number of identical fittings per unit was increased and the design of the fitting simplified. The final result was a savings of about $1,700 realized by designing the parts as forgings, although on the basis of opinion it seemed that machining the part from a billet would be cheaper.

In another instance, a manufacturer set four production design engineers and two cost analysts working for two weeks to investigate the design of an airplane component which was greatly exceeding its estimated cost. Eighty-three potential change items were considered. Twenty-one of these items resulted in no overall savings and were rejected. The remaining sixty-two items represented a potential savings of more than $52,000. A significant fact here is that this analysis indicated an additional saving of more than $70,000 in the production of an additional quantity of two hundred units for each component, which savings were reflected in the subsequent bid made by the company for an additional order. All of these savings added approximately only $4,000 to the engineering cost of this project, but of course the cost analysis had available the results of a number of previous cost studies and comparative figures. Some of the detailed cost studies that were made covered the cost of welded versus machined assemblies of bellcranks, the relative costs of bolting, spot welding and riveting, and many other detail operations.

Finally, another of the country's leading manufacturers has had a cost control group in operation for more than five years. At the present time there are nine men in this group which represents about one-half of one percent of the engineering personnel of the company. The activities of this group have been so fruitful that the company is planning to increase the appropriation for cost control operations to one or two percent

of the total engineering department costs. It was estimated that during one year of operation the six man cost control group achieved a potential savings of more than $1,500,000. During that year the group made about 120 formal cost analyses. In the previous years they had made 66 analyses which showed an estimated savings of over a half million dollars.

The savings shown in all of these case histories were direct savings resulting from applied cost analysis. The secondary savings probably equalled, if not exceeded, the direct savings. The designers in these various departments became cost conscious, for at last their designs could be evaluated costwise in terms of figures. Management had taken sufficient interest in the cost problem to afford them a previously missing means of measurement. Product cost evaluation began to approach its rightful importance. The response from designers was gratifying. Essentially, any designer is willing to do a better job if there is some absolute or conrete means of establishing and determining that a better job is done. Men who have been educated and experienced with scientific means of measurement have a natural reluctance to accept a guess or opinion as being fact. Cost analysis provides these facts.

Functions of a Cost Control Group

The function of the design cost control engineers is primarily to serve as design cost specialists, make detailed cost estimates as required, aid in the preparation of compiling standard cost data and prepared cost reports and cost summaries for the designers' use. It is distinctly a service function for the design groups. The natural starting point for a cost control group is in the determination of the least expensive detailed design when engineering requirements permit alternative designs, such as, for example, the relative cost of a fitting which may be forged, cast, or machined from bar stock. The activity of this group can later be expanded to include minor and major assembly designs. In the experiences of one company, about half of the cost analyses were made upon the request of the designer and the remaining half were originated by the cost people working in the design group. Significantly, the cost analysis recommendations received about eighty percent acceptance by the group engineers.

It was found in the case of one manufacturer that most cost analyses required about twenty or thirty man hours of work, although some required as high as three hundred hours. All the comparative cost analysis work was done in extreme detail. Material costs were based on current price, furnished by vendors and supplemented by purchasing records. Labor costs were determined by applying time study standards to each operation, which standards were compiled in a standard data book after having been obtained primarily from the time study department. However, the design cost control group created and supplemented a great deal of this data. Tool costs were originally obtained from the factory tool estimating department and checked by the design cost control group.

From various data collected and cost analyses made, brochures were prepared for distribution to the engineering department. These brochures included charts of raw stock costs in graphic form, listing prices against unit of length, area, or volume, as the case might be. Another brochure consisted primarily of summary sheets of past comparative cost analyses of detailed parts. Another highly interesting brochure listed the installed costs of various standard assembly fasteners such as bolts, blind rivets, standard rivets and similar fasteners.

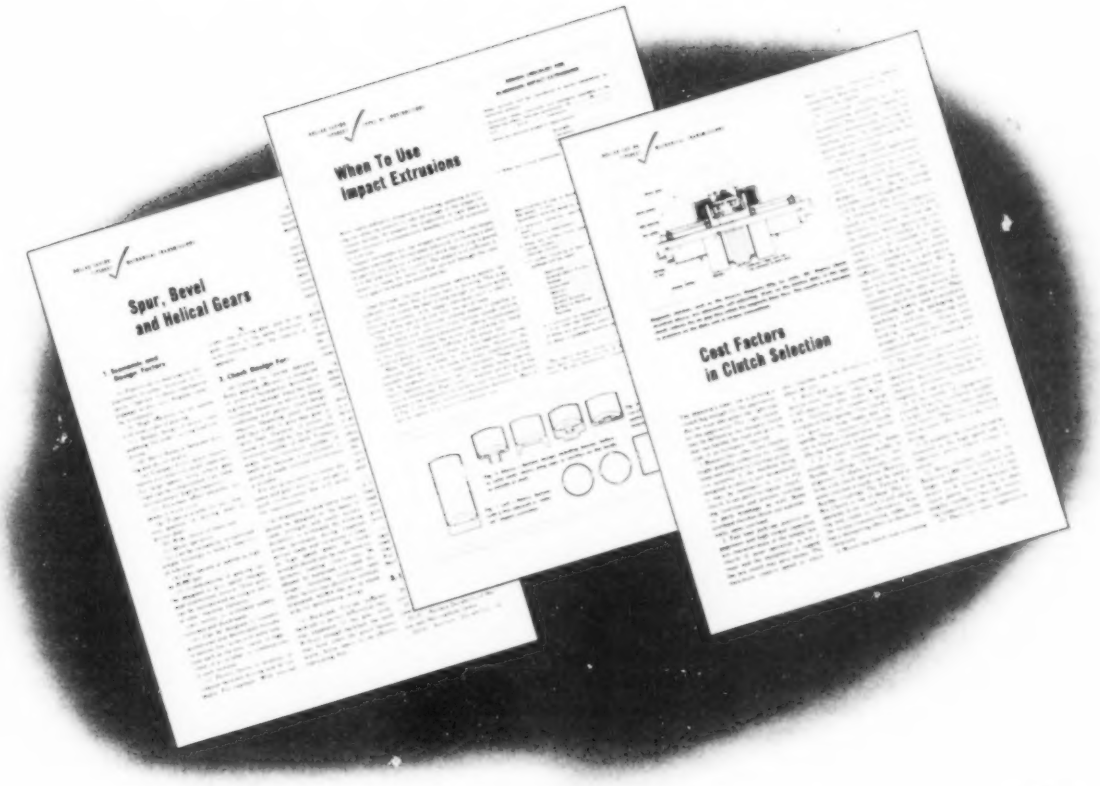
In a cost control operation there are no overlapping duties between cost control groups and the factory estimating department, although there may be an interchange of personnel. However, the operation of a cost analysis group can also be applied in determining cost estimates when making proposals or bids if so desired. A well-organized cost analysis department, backed up by proper data, will eliminate much of the detail estimating on proposals, will reduce the time required to make a proposal, and will end up with a rock bottom competitive cost.

Finally, there is a third reason for cost analysis, namely, to establish directions and objectives with reference to costs in design developments. It is futile to add sales values to a product if the increased cost of achieving those sales values is in excess of the increased dollar sales value of the improved design. By cost studies it is often possible to steer the product development programs so that they will stay in line with commercial objectives rather than shunting off into the realm of unprofitable idealism.

In short, price competiton and producibility requirements are bringing more attention to the economies of engineering design. Engineering personnel trained and developed during the war are generally not well developed in principles of cost. A course in instruction on cost principles for key-engineering personnel will usually be found profitable. The engineering attitude toward design economies must be developed and controlled to avoid overemphasis. Any cost-instruction program for engineers should also place emphasis on controlling engineering department operating cost as well as the design influence on production cost.

Admittedly, administration of any cost control program must be supported by sufficient drive and authority to complete agreements among the various design viewpoints. The final decisions cannot be made solely on the basis of numbers arrived at by cost analysis. There is always the problem of balancing values and costs. There is also the problem of shop equipment available and the skills and know-how of the shop personnel. Because of such factors, sometimes the most economical construction on the basis of cost data will be the most expensive to apply. But only by the establishment of a competent cost design group can these factors be determined.

It must not be assumed, however, that a collection of cost data and its use will assure designs of lowest cost. Comparative cost estimates are merely for selecting the most economical design of those that are proposed. Such relative cost estimates do not in themselves give any assurance that there is not another design that has not been proposed but that will be much cheaper. Thus, only by exercising design ingenuity can the minimum cost goal be achieved.



Why Dollar Saving *Tipsheets?*

COST ANALYSIS is for the purpose of determining the relative total manufacturing cost of the various designs proposed or developed by the engineers. However, there is no assurance that the most economical design is included among the proposed designs. Nor is it the responsibility of the cost analysts to ferret out a design which will be the cheapest to manufacture. That function is generally the responsibility of the design engineer.

Ironically, in many engineering departments design changes to be made to reduce costs are decided in committee meetings. As stated by one chief engineer, "Our background of experience and our knowledge of costs enable us to quickly decide on the most economical design. We simply have a committee meeting of the production engineers, the process engineers and the designers and then decide on how we are going to make it. Sometimes if there are radical changes to be made in the product, the sales executives also sit in on the meeting." Presumably the "Deciding Committee Procedure" might be the most effective approach to the relative-cost problem for certain types of small products. There are designs wherein the range of possible methods and constructions that might be used is extremely narrow. This is true of many electrical designs wherein the required electrical properties of the materials reduce the possible selection from among only a few.

Granted that the committee system is effective to a degree and that there is no formula for reducing cost to the minimum, yet there are methodical procedures that could be followed. Admittedly, it is not possible for any practical procedure to guarantee that the best results will be achieved and in the final analysis, the success or failure in designing with dollars hinges entirely on the ability and ingenuity of the design engineers involved. But any degree of methodical procedure that might be instituted will serve to make more effective and efficient the work of these designers. One design tool for such a methodical procedure is the compilation and use of "tipsheets."

Among the following pages will be found various examples of "Dollar-Saving Tipsheets." These have been worked up with the cooperation of many design engineers in industry. Obviously many more such check sheets could be developed for parts and components not presented here. Likewise, there is no claim that the tipsheets on the following pages are complete and sufficiently comprehensive. It is hoped that with this start

design engineers in various companies will further develop such lists and notations. Interested industries could also contribute suggestions to be added and further check sheets on additional subjects.

In so far as the editors of PRODUCT ENGINEERING know, there is no engineering department that makes use of such suggestion check lists in the development of low cost designs. But in almost every engineering department there are random cost sheets, cost memorandums and invariably much handbook material in the engineering department's manuals to aid in cost reduction. The type of suggestion check lists presented here are merely for the purpose of consolidating such data and information by grouping on the basis of the machine elements, components and constructions that serve as a common denominator.

It is not to be expected that initially the "Dollar-Saving Tipsheets" will always include every cost saving design possibility. In making up the check sheets initially, some possibilities will likely be overlooked. Also, as time passes there will be industrial developments that will present new cost saving possibilities that can and should be incorporated in the listing. Thus as the new materials, components, parts and processes are developed they should be entered on appropriate lists.

The suggestion check sheets are not built around the finished product or any specific completed design. Rather, they relate to the materials, elements and components of products and machinery. There may be a suggestion check sheet on power transmissions between shafts. Such a sheet would list and comment on the various types of gears, chain belts and flexible belts that might be used and would include mere mentions of associated design savings that might accrue in the application of one or the other types of elements.

In using these sheets the designer should be extremely cautious about discarding from consideration suggestions that at first glance appear out of line cost-wise. Previous experience and a knowledge of the basic costs involved will in many instances clearly indicate that a certain suggestion is far more costly than some of the others. In such a case, the suggestion can be safely discarded. However, there are many instances wherein an apparently high cost suggestion turns out to be the most economical one to use.

Stainless steel at several times the price of carbon steel might well be the cheaper of the two to use. A phosphorus bronze spring wire with a rolled gold cladding to make it corrosion resistant might well add many times its cost to the sales value of the product. Aluminum castings after being machined and finished might cost less than the equivalent casting in gray iron. Or a fabricated part made up of a number of castings welded together might well be far cheaper than either a single casting or a welded steel assembly.

In the field of parts and components, two electric motors have often been found cheaper than one. Low inertia of rotating parts by making them of more expensive light metal sometimes saves the added cost of the light metal several times over by making possible the use of a smaller motor. Fluid couplings can sometimes pay a good portion of their total cost by virtue of the smaller horsepower motor or engine that might be required for starting conditions, in addition to which there are often further savings in associated parts. Two motor driven hydraulic power packs used on a large machine might be more economical than one because of the savings in piping, valving and similar factors.

Usually it is necessary for the design engineer to make at least rough layouts of the various designs in order to give the cost analysts sufficient information to work upon. In making these layouts the designer should be extremely careful to include all the associated design features that might affect the total costs. In some instances it might be necessary to think the design through to the finished product. The difference in finishing costs between a gray iron sand casting and an aluminum sand casting may be a considerable item.

The tip sheets have been arbitrarily classified into seven categories. Naturally such a breakdown can be as extensive or superficial as necessary, depending on the type of product or products that are made by any one manufacturer. In some cases it might be imperative to break down electrical wiring, for example, into such subjects as types of connectors, type of wiring, control panels, and others. Or it might be necessary to have tip sheets on all forms of gearing, on lubricating devices for machinery, on types and classes of antifriction bearings, and other mechanical components.

However, for purposes of this presentation the following tip sheets have been prepared as lists to be checked to arrive at the most economical part. Included in this presentation are short articles listing some of the approaches that should be considered when selecting or specifying a part or component. Still others consist of hints, tables, and data.

TIPSHEET CLASSIFICATION

Mechanical Transmissions—Gears—Bearings—Chain drives—Gear reducers—V-Belts—Clutches—Couplings—Brakes

Fastenings, Mountings, and Mechanical Parts—Snap Fasteners—Screw fasteners—Bolts and screws

Types of Constructions—Precision castings—Sand castings—Precision tubes—Forgings and hot pressings—Die castings—Powder metal parts—Screw machine parts—Cold headed parts—Impact extrusions—Cold roll formed sections—Stampings—Spun parts

Materials—Ferrous—Non-ferrous—Plastics—Organic finishes

Processes—Brazing—Resistance Welding—Fusion Welding

Hydraulic and Pneumatic Components

Electrical Devices and Equipment—Wiring—Motors—Controls

V-Belt Drives

1. Economic and design considerations that should be analyzed when selecting V-belt machine drives.

(a) Simple, inexpensive and efficient form of drive for machines where requirements do not demand an absolutely fixed speed ratio of drives to driven shaft.

(b) Their inherent ability to stretch under load enables them to absorb a portion of the shock of suddenly applied loads, and thus protect to some extent both the prime mover and the driven machine.

(c) Smooth running, silent, and free of vibration when sheaves are statically and dynamically balanced.

(d) Speed ratios can be varied when variable pitch sheaves are used; some types can be adjusted when machine is in motion.

(e) Short center drive installation makes for compact driving arrangements. Center to center distance is not fixed by speed ratio; large number of standard belt lengths is available to suit a range of center to center distances.

(f) V-belts can be used between a grooved small sheave and a flat-face large pulley when a speed ratio of three to one or greater is used.

(g) V-belts can be manufactured to meet practically any atmospheric condition. Belts can be constructed of leather, fabric, rubber, and suitable impregnating materials to resist heat, abrasion, or oil, and to dissipate static charges.

(h) No stoppage in production should a belt failure occur; with a multiple strand drive the remaining belts will carry the load until full replacement can be made.

2. Check design for:

(a) SHEAVE DIAMETERS. Permissible pitch line speeds generally range from a minimum of 1,000 to a maximum of 5,000 fpm. Life of drive increases with diameter of sheaves, but compactness is sacrificed. Use of large sheaves in a multiple drive might achieve an appreciable saving in number of belts and width of sheave; in some applications the WK^2 of the sheave may be reduced. With width reduced, less shaft overhang may result. With same size belt, increasing sheave diameter gives an increased power rating that can be used as an additional factor of safety.

(b) CENTER TO CENTER DISTANCE. Center to center distance should always be great enough to obtain a minimum arc of contact of 90 deg on smaller sheave. A greater distance is desirable. Increasing the arc of contact increases the power rating of the belt. Center to center distance should be selected to suit available standardized lengths of endless belts.

(c) BELT PULL. Power transmitted, pulley diameters, speed, and arc of contact determine belt pull. To equalize pull on multiple belts, shafts must be kept parallel.

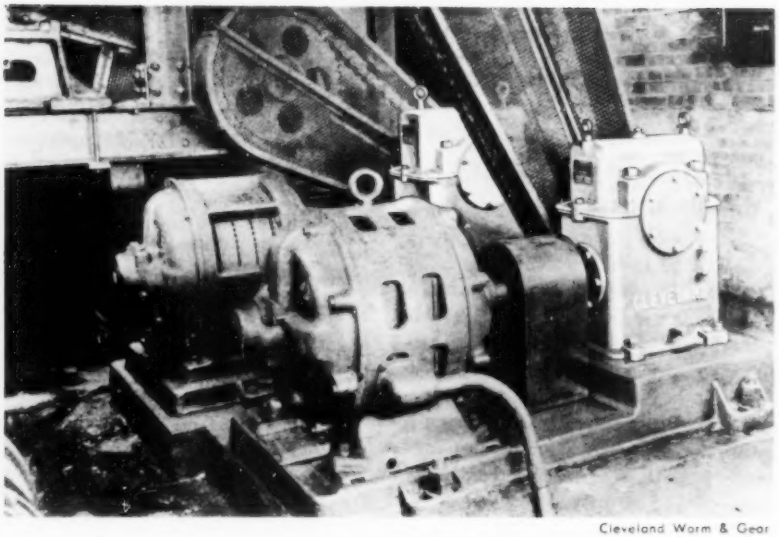
(d) SIZE AND NUMBER OF BELTS. These should be determined on basis of peak loads and possible overloads, which do not necessarily correspond with the horsepower rating of the motor. For any particular drive it is necessary to apply to the normal rating, service factors as determined by the characteristics of the prime mover and the driven machine such as starting torque, stalled load torque, torques required to accelerate load at intervals in the work cycle; and torque required to brake load when stopping. The fewer the number of strands used, the narrower become the sheaves and the mounting space needed. Nylon or steel core V-belts should be investigated.

(e) LIFE OF DRIVE. The durability of a belt drive depends upon not only the maximum pull in the belt and the relative sizes of sheave diameters, but also on the total length of belt and the difference in the diameters of driving and driven sheaves. The fatigue of belts, which results from the loss of resiliency, increases with the rate of flexing per revolution.

(f) MOUNTING ARRANGEMENTS. Provide space to take off and put on belts, even though sheaves are on outboard shafts. One sheave should be sufficiently movable to shorten the running center to center distance by an amount at least as great as the belt thickness to facilitate applying the belt without forcing. The sheave should also be sufficiently movable in the other direction to take up 3 percent of the circumferential length of the belt to take up stretch in service. Sliding bases are generally used to obtain space for applying and adjusting belt tension. Pivoted motor mountings, though in some designs difficult to include, also take up slack as the belt stretches under load and reduce slip. In designs where sheaves are straddle mounted between bearings, belts longer than needed are used to facilitate installing belts and the excess length is taken up with adjustable idler pulleys; this arrangement can be also used to increase arc of contact.

(g) FLEXIBILITY. Machines driven through V-belt transmissions make possible the design of self-contained units. The short centers attainable with V-belts permit convenient location of the motor on the frame of the driven machine.

DOLLAR SAVING TIPSHEET ✓ MECHANICAL TRANSMISSIONS



Cleveland Worm & Gear

Gear reducer used in conjunction with a chain drive on the low speed end to obtain the necessary speed reduction.

What Adds to the Cost of Gear Reducers?

The major factors affecting the cost of speed reducers are (1) the type of gearing used; (2) the reduction ratio that is required; (3) the construction of the unit; (4) the horsepower capacity of the unit; (5) and methods of connecting the reducer to the load.

Following are some check points that should be investigated when applying a reducer. For purposes of simplicity, they have been classified under two headings: speed reduction, and method of connection to the motor and the load.

Speed Reduction

Type of gearing to be used is one of the first considerations. (See Gear Tipsheet). If a single reduction gear train will not suffice, a double or triple reduction helical or double herringbone unit may be required. Worm gear reducers will provide a high reduction in a single gear train. Noise may be a factor in selection of the gearing.

Perhaps the casing for the reducer can be cast into the base or frame of the machine, in which case only standard gearing must be bought from the outside. This is sometimes an economy.

Gearhead motors are satisfactory for many applications, but such motors are made in a limited number of types and capacity ranges, and often do not provide the necessary flexibility for connection to a load. They nevertheless are compact and sometimes less expensive than a separate motor and gear reducer.

It is not only the application, but also the gearing that determines the bearing construction of the reducer, and the cost differential between sleeve bearing and anti-friction bearing construction may be considerable. Ball bearings usually are used for the common motor speeds. Sleeve bearings are sometimes used for herringbone reducers among others.

In some instances it is more economical to use two motors having different speed ratings to drive a reducer, one on each end of an extended input shaft, than to use a d-c or adjustable-speed a-c drive.

Two or four-speed motors add flexibility to a gear reducer drive. But in the majority of cases, a gear reducer is used only to obtain a fixed output speed.

In integral horsepower sizes it usually is not practical to arrange reducers in series – the low speed end of one driving into the high speed end of another – to multiply speed reduction. Where large reduction ratios are required, multiple reductions can usually be provided in a single housing, minimizing space and coupling requirements.

Connection to Motor and Load

Both low and high speed ends normally are connected through flexible couplings because shaft alignment is less critical and costly, and because shock loads are dampened, thus prolonging the gear life.

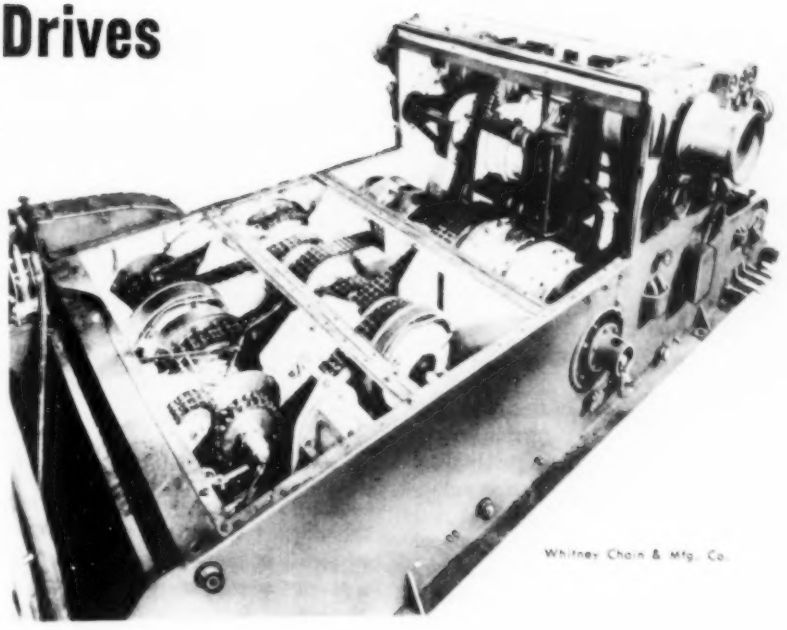
Fluid couplings of the traction type can be substituted for the flexible coupling between the motor and the gear reducer at a sacrifice in first cost, but the power application on the load is much softer, and stalling of the load does not overload the reducer or motor.

Fluid couplings of the dump type are expensive, but can be used with speed reducers to provide some degree of speed control, or to obtain overload protection and load disconnection.

Magnetic couplings and air couplings also are expensive, but slippage can be controlled and rapid load disconnection is insured – from a remote control station, if required.

Frequently it is more economical to use a chain drive as shown in the illustration or Vee belt in conjunction with a speed reducer to obtain the necessary reduction ratio rather than to get the necessary ratio entirely in the reducer. Vee belts are generally used on the high speed end, chain drives on the low speed end. Cost of a supplementary drive is partially paid for by the elimination of the flexible coupling.

Chain Drives



1. Economic and Design Factors

(a) Positive drive, no mechanical slippage. High efficiency. Long life.
(b) Low maintenance or upkeep cost.
(c) Readily assembled, installed, and replaced.
(d) Permits some variation in center to center distance of driving and driven shafts.
(e) Will operate at any angle in a plane, from horizontal to vertical.
(f) One chain can drive more than one shaft, thus offering flexibility in relative shaft positions.
(g) No initial tension required.
(h) Strength to size ratio is high.
(i) Available in many standard types, sizes and materials.

2. Check Design for:

(a) SPROCKET ARRANGEMENT. Most favorable position for a chain drive is that in which the center line of the sprockets is horizontal; drives at angles not exceeding 60 deg from the horizontal are efficient. Vertical drives may give difficulties.

(b) CHAIN SPEED. For general service, recommended maximum speeds for standard roller chain range from 2,000 ft per min for a ½ in. pitch to 1,000 ft per min for a 2 in. pitch.

(c) PITCH. Speed of the faster running shaft, chain speed, power transmitted, number of strands in chain, expected life, service factor, and tensile strength of chain are factors that must be considered when establishing the pitch. Often multiple strands of fine pitch are better than a single strand of coarse pitch.

When pitch of chain is decreased and the pitch diameter of the driving sprockets kept the same:

1. Chain speed remains the same.
2. Effective chain tension required remains the same.
3. Number of teeth in sprocket is increased, therefore, the chain links in going on and off the sprockets swing through a smaller angle thus reducing impact of chain on sprocket and giving smoother running.
4. Noise from impact is less.
5. Chain life is increased in proportion to the decreased wear and impact.

(d) NUMBER OF SPROCKET TEETH. For efficient performance of slow-speed drives, the pinion sprocket should have at least 9 teeth; for high-speed drives, not less than 15 teeth.

When number of teeth in the driving sprocket is increased and the pitch of the chain remains the same:

1. Pitch diameter of the sprocket increases.
2. Chain speed increases and the effective chain tension required decreases proportionately.
3. Noise, impact, wear, and variations in angular velocity are decreased.
4. Service life of chain is lengthened.

(e) RATING MODIFICATION OR SERVICE FACTORS. Power ratings for roller chain as published by chain manufacturers are conservatively based on a wide experience covering all industrial uses. The important factor, at medium and high speeds, in establishing an allowable working load is area of pin-bushing bearing.

Chain selection may be based upon the manufacturers power ratings when:

1. Drive is for intermittent or stand-by service; less than maximum service life is required; speeds are extremely slow; centers are unusually long; and lubrication is exceptionally good.

The ultimate tensile strength modified by a suitable factor of safety should be further modified by a percentage factor in determining the allowable working load when:

1. Pinion sprocket in a slow-speed drive has less than 9 teeth; in a high-speed drive has less than 15 teeth; loading is impulsive; two or more shafts are driven from the same sprocket; or lubrication is poor.

Ratings published by manufacturers include allowances for centrifugal force.

(f) CHAIN LIFE. Properly selected chains wear out rather than break. Life of chain chosen should be commensurate with that of the machine. Overloads reduce chain life sharply. Chain life increases with the quality and effectiveness of lubrication.

DOLLAR SAVING TIPSHEET / MECHANICAL TRANSMISSIONS

Spur, Bevel and Helical Gears

1. Economic and Design Factors

(a) Positive drive and angular displacement in either direction of rotation. Operate without mechanical slippage, at any ratio. Angular velocity is constant.

(b) High efficiency at all speeds with most types of gearing.

(c) Simple design of power train and long life under varying load conditions.

(d) Short distance between driving and driven shafts.

(e) Compact drive; space requirements are relatively small, especially for large speed ratios where gear train can be compounded. Can transmit extremely high horsepower.

(f) Flywheel effect smooths out peaks in work cycle.

(g) Types available for any relative position of driving shaft to driven shaft.

(h) Wide choice of materials.

(i) Quiet operation.

(j) Can be inclosed by streamlined simple housings to hold a reservoir of lubricant.

(k) Can operate at speeds as high as 20,000 fpm.

(l) Combinations of gearing can be designed to give speed changes, and intermittent motion. Often gears can be incorporated as integral parts of other machine elements.

(m) Ability to withstand sudden reversals and shock loads.

(n) Can be designed to transmit accelerated and decelerated motions; or motion that varies with some function such as the sine, cosine, or logarithm of a variable; or combinations of such motions.

(o) Permit choice of direction of rotation between driving and driven shafts. For example: With internal types, the driving gear and driven gear rotate in the same direction; with external types, the rotation is opposite.

2. Check Design For:

(a) CENTER TO CENTER DISTANCE. Since gearing efficiency is measured in terms of horsepower delivered in a given size package, keep the center to center distance as short as design conditions will permit. Good design requires balancing pitch diameter and face width to give best gear to carry load. Diameter of pinion, of course, is limited by the permissible minimum number of teeth. Pressure angle limits minimum number of teeth only because of interference; if pinion is made oversize interference is avoided.

For any given center to center distance and gear ratio, only one pair of pitch circles exists that will satisfy the requirements.

(b) STRENGTH OF GEAR TEETH. Gears should be designed on the basis of tooth strength and tooth surface durability to withstand the working stress developed during expected service loads, and variations in load. In high speed gears, the tooth strength should also be calculated for dynamic loading. Gears may be abused by sustained overloads, improper mounting conditions and other factors that should be carefully evaluated. AGMA has set up standards for determining ratings.

(c) BACKLASH. Provide sufficient backlash to permit differential thermal expansion of the gear teeth. Without enough backlash, the teeth may bind when the gears become warm. Allow space for an effective lubricating film.

(d) REVERSING DRIVES. Specify minimum backlash required and minimum end play in the bearing assembly.

(e) BEARING LOADS. Bearing loads increase as the tooth pressure angle increases. To avoid excessive bearing loads and shaft deflections in motors, minimum diameters of pinions have been established by motor manufacturers on the basis of power transmitted, speed and pressure angle of tooth.

(f) TOLERANCE FOR ALIGNMENT. Angular misalignment of shafts in any plane prevents a uniform distribution of load across gear teeth. Misalignment with consequent gear wear can be reduced to a minimum by supporting the shafts in rigid bearings as close to the gears as possible.

(g) BEARINGS. Outboard bearings should be provided wherever possible to prevent shaft deflection under load.

(h) THRUST. Adequate provisions should be made to take care of thrust in worm gearing, helical, spiral bevel, bevel, and hypoid gears. In spiral bevel gearing, when the drive is always in one direction, the thrust of the gears should be controlled in a direction opposite to the intersecting point of the pitch cones; when the drive is reversing, thrust should be taken care of in both directions on the gear and pinion.

(i) HUNTING. Avoid the recurrence of the flywheel effect of high inertia loads, and the recurrence of the high load peaks in varying work cycles coming on the same gear tooth or groups of teeth. Wherever possible avoid integral ratios.

(j) GEAR BLANKS. Blanks should be rigid enough to withstand applied loads. Many design failures can be traced to improperly designed blanks. For guidance in blank section see Section 8 of AGMA Standard 236.02.

3. Standards

The following AGMA standards contain valuable design data:

210.01 – Surface Durability of Spur Gears.

211.01 – Surface Durability of Helical and Herringbone Gears.

212.01 – Surface Durability [illegible]

Straight Bevel and Spiral Bevel Gears.

220.01 – Strength of Spur Gear Teeth.

221.01 – Strength of Helical and Herringbone Teeth.

222.01 – Beam Strength of Straight Bevel and Spiral Bevel Gears.

236.02 – Inspection of Fine Pitch Gears.

4. Types of Gears and Their Uses

In designing a gear train the following factors, in order of their importance, should be considered by the designer. The ratio and kind of drive necessary to obtain the correct speed and direction of motion must be determined. From this a choice of kind of gearing is made.

SPUR GEARS: Use of spur gears should be investigated:

(a) When the shafts are parallel.

(b) For speeds generally under 1000 surface fpm.

(c) When there are no high impact loads.

(d) When no special provisions are made for thrust.

(e) Where no fast reciprocating parts are attached to the shafts of, and driven by, the gears such as cams, cranks, pistons, and similar components.

(f) Where a high degree of quietness or extreme smoothness of operation is not required.

(g) When cost is a factor. Spur gears can generally be produced more cheaply than any other type.

HELICAL GEARS: Use of helical gears, with parallel shafts should be considered:

(a) Where a high degree of quietness and smoothness of operation is required.

(b) Generally for speeds exceeding 1000 surface feet per minute.

(c) Where fast reciprocating parts must be driven by gears.

(d) Where adequate thrust provisions can be provided.

(e) Where there are relatively high impact loads.

BEVEL GEARS: Used for right-angle drives where the shafts intersect. There are several types of bevel gears: Straight bevels, spiral bevels and Zerol. Adequate thrust provisions must be made when using spiral bevel gears.

FACE GEARS: Used for right-angle drives where the loads are relatively light. Face gears usually engage a spur pinion that can be moved on its axis across the face of the gear without loss of efficiency. For this reason the problem of mounting is simplified.

HYPOID GEARS: Used for right-angle drives where the shaft axes cannot intersect. They have all the virtues of spiral bevel gears. In addition, they usually have a greater load carrying capacity.

OFFSET FACE GEARS: Used for right-angle drives when the shaft axes cannot intersect. Their load carrying capacity is approximately the same as "on-center" face gears. They can be used for drives where the loads are relatively light. Like the "on-center" type, the pinion can be moved on its axis without impairing tooth action. In this type of gearing the choice of ratio is somewhat restricted. This qualification applies to both the "on-center" and "offset" types. Ratios of one-to-one are not practical and the pinion must always be smaller than the gear. The most practical applications are those where the gear diameter is at least one-half greater than the pinion diameter. Face gears also have greater restrictions on face width than bevel gears of equal pitch.

WORM GEARS: Used when high reductions are required. There are several types of worm gears, the most common being the type in which the gear partially envelops the worm. In another type the worm is shaped like an hour-glass and is usually made as an involute helicoid. The mating member is a helical gear. The amount by which the worm envelops its mating helical gear varies with the ratio, pitch and pressure angle.

5. Basic Considerations

Having selected the type of gearing best suited for the particular drive the designer must next make a choice of:

(a) Material (maximum fiber stress, psi) $= s$
(b) Pitch (circular pitch, in.) $= p$
(c) Width (of face of gear, in.) $= F$
(d) Tooth Form (tooth form factor) $= y$

Given in this order, these fundamentals outline the pattern of the familiar Lewis Formula, $spFy = W =$ transmitted tooth load in pounds, used for determining the beam strength of spur gear teeth. While this formula is conservative and is subject to modifications by speed and accuracy factors, it serves its purpose in the early stages of the design process. Knowing the center distance, gear ratio, and tooth load it is possible to determine the circular pitch and face width. The minimum recommended circular pitch for a gear application is one that will provide at least ten teeth in the pinion.

6. Economic Considerations

Do not specify gears that are more accurate and precise than the application requires. The AGMA recognizes four types of gears classified according to accuracy of tooth profile, allowable backlash, runout and accumulated error. Naturally, the higher the precision specified the greater the cost. Following are the AGMA classifications of gears:

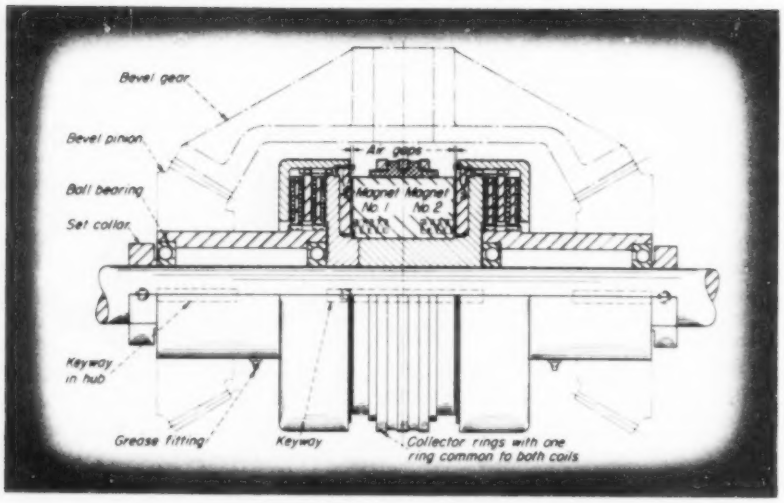
COARSE PITCH GEARS
Precision high-speed over 2,000 fpm
Commercial high-speed up to 2,000 fpm
Commercial medium speed up to 400 fpm
Low speed up to 80 fpm

FINE PITCH GEARS
Precision Class 2 or 3 over 2,000 fpm
Precision Class 1 up to 2,000 fpm
Commercial Class 3 up to 400 fpm
Commercial Class 1 or 2 up to 80 fpm

Another controlling cost factor is the gear material. If the gear is designed to operate under low unit loads, cast iron might be suitable. For high speed gears transmitting high horsepower, as in aircraft gearing, high-alloy heat-treated gears manufactured to the closest tolerance obtainable are required.

Loads, speeds, expected life, service conditions such as lubrication, ambient temperatures, shock loads and similar factors will determine the type and class of gearing required.

The smaller the gears the less will be the effects of inertia and dynamic unbalance. For high rpm correspondingly small high-alloy gears heat-treated may prove more economical than larger gears of lower strength materials and less precision. The associated economies of a more compact design must also be considered.



Magnetic clutches, such as the Stearns Magnetic Mfg. Co. style "ED" Duplex Clutch sketched above, are inherently self-adjusting. Wear on the friction disks of this type clutch reduces the air gap thru which the magnetic lines flow. This results in an increase in pressure on the disks and in torque transmitted.

Cost Factors in Clutch Selection

THE DESIGNER'S FIRST JOB is picking a clutch big enough for the application. But he must also select the right type for the application. The "right clutch" may be defined as the cheapest clutch that can handle the load and give the type of performance required.

1. Besides their other uses, clutches might possibly substitute for complicated and expensive overload protective systems. If the machine being designed is likely to jam occasionally, it may be necessary to try a *slip clutch*. It can perform regular clutching functions and prevent overload or parts breakage as well. Some *overload clutches* throw out automatically upon overload.

2. Fast load pick-up, positive engagement and high torque capacities are characteristics of the simple *jaw clutch*. If quiet operation is not a must and the equipment is rugged, the jaw clutch may save money. The maximum rotative speed at which jaw clutches can be thrown in is about 60 rpm.

3. *Multi-disk*, jaw clutches and *double-cone* clutches require less shaft space than other types. *Multi-disk* clutches can transmit large torques at high speeds. *Cone* clutches are good for large loads and low speeds. These clutches will contribute to machine compactness, thereby offering associated economies.

4. It is poor economy to make standard type clutches double as flexible couplings. Ordinarily, misalignment of shafts seriously interferes with clutch operation. However, some clutches actually can be used as flexible couplings. The Fawick Airflex Clutch is one of these. This air-operated drum clutch is self-adjusting and needs no lubrication. Also, the torque-transmitting rubber tube has a dampening effect on shocks and vibrations.

5. Mount the clutch close to existing *shaft bearings*. Otherwise, special supporting bearings must be provided for the clutch.

6. *Centrifugal clutches* are ideal for connecting gasoline engines to equipment. They provide a low cost means for automatically starting the machine when the engine is up to speed and also for protecting the machine against overload.

7. For average clutch applications, standard *linings* are entirely satisfactory. However, where service is severe and long clutch life a requirement, it might be cheaper for the designer to specify the best linings available, even though their first cost will be considerably greater.

8. Ordinarily, the more foolproof a clutch is, the more it costs. It is well, therefore, to consider the end-use of the machine before specifying components such as clutches. If the machine is to be installed in places where it will be given regular maintenance, a *standard clutch* is usually sufficient. Otherwise, a *self-adjusting clutch* may be necessary. But be sure to furnish the machine user with full instructions on lubrication, adjustments and the other factors that influence clutch life and service.

9. The *single revolution clutch* is an economical and efficient means for obtaining intermittent motions in machines. Such clutches may be mechanical, pneumatic, hydraulic or magnetic in operation. They are already widely used in automatic machinery such as packaging and bottling machines; indexing and feeding equipment; shears and presses in place of more costly and complicated means of obtaining intermittent motions.

10. If the number of engagements exceeds 15 per hr, it is better to select a larger clutch than torque calculations call for. Otherwise, overheating may seriously affect life of the *clutch facings*.

11. If possible, the clutch should be mounted on the high speed side of *reduction gears*, where torque is lowest.

12. Some clutches, such as the Rockford LMS, are furnished with longer bodies to permit a *V-belt sheave* to be mounted between the clutch plates, thus saving on shaft lengths, number of bearings, mounting supports and other accessories.

13. There are many applications

where *free-wheeling or overrunning clutches* can be applied with economy. For example, if a load is driven by two motors, an overrunning clutch can be placed between each motor and the load. Then, either motor is automatically connected to or isolated from the machine simply by operating the motor switch. Compare the cost of this set-up with the cost of any other automatic clutching scheme. Another solution might be the use of *mercury clutches.*

Economic Considerations

The cost of an in and out clutch installation includes the installed cost of the element (the clutch), plus the cost of the control mechanism required. Thus, the total cost of a mechanical clutch includes the cost of the control levers and rods required. Pneumatic or hydraulic cylinders at the clutch might be used to actuate it, in which case hydraulic or pneumatic lines and valves must be furnished. For pneumatically operated clutches the control need be only a valve plus single air line to clutch. Magnetic clutches require merely the necessary conductors from the control station to the clutch.

Contributors to the above list include Morse Chain Co.; Stearns Magnetic Mfg. Co.; Rockford Clutch Division of Borg-Warner; Fawick Airflex Co., Inc.; W. A. Jones Foundry and Machine Co.; The Carlyle Johnson Machine Co.; and Twin Disc Clutch Co.

Selection of Rolling Contact Bearings

To REALIZE true design economy, the designer must select ball or roller bearing that will operate efficiently and that will last the required amount of time. But, on the other hand, he must not "overdesign" or specify a bearing that is just too good for the job it has to do. Bearing cost is directly related to running accuracy.

The four general classifications of ball bearings are listed below in the order of increasing cost and running accuracy.

1. *Stamped bearings* are satisfactory for light loads, slow speeds and intermittent operation. If his requirements are limited, the designer can obtain at little cost the advantages typical of rolling friction bearings by specifying stamped bearings.

2. *Commercial bearings* are widely used. In many cases, the designer will find these bearings adequate. For cost reasons, he should try to standardize on the commercial grade unless higher precision is definitely indicated.

3. *Precision bearings* represent a compromise between the lower cost of the commercial grade and the running accuracy of the super precision grade.

4. *Super precision bearings* are for applications such as machine tools. If this type is used, the engineer must make sure that the rest of his design is sufficiently accurate to take full advantage of the precision bearing he is paying for. For example, a misaligned housing will nullify any benefits offered by a precision bearing.

Tips on Bearing Selection

Special bearings may contribute to design economies. It is possible for a designer to make portions of his machine function as parts of the bearing. For example, an inner race might be machined directly into a shaft. Or, an outer race can be cut into a casting that will function as the bearing housing.

Choose the *bearing series* that is most suitable for the application, from the standpoint of capacity and dimensions.

Use light-series bearings for moderate loads and large shaft sizes. This series should be specified also where the housing space available requires the smallest bearing width and shortest outside diameter practical for a given bore size.

..Medium-series bearings carry heavy loads and afford a high ratio of bearing capacity to shaft size.

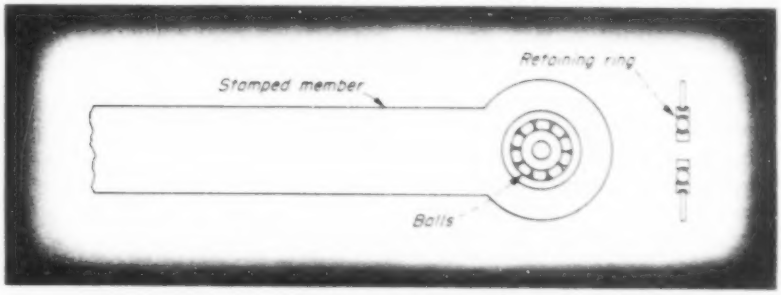
Heavy-series bearings are applied only to specially proportioned shafts and are recommended only for special applications.

In addition to economical bearing selection, the machine designer must consider the following:

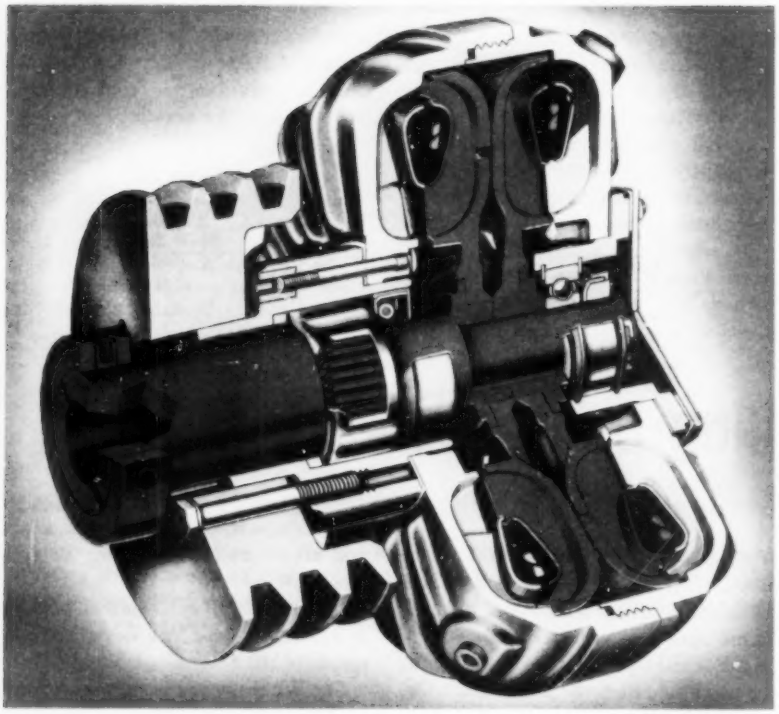
(1) Where there is no thrust load, and axial shaft movement does not have to be closely restricted, *housing design* can be simple and economical. Housings can be bored straight through without shoulders. If there is thrust, retaining rings can be used instead of a machined shoulder.

(2) Avoid using more than 2 bearings on a single shaft because of alignment difficulties.

(3) Oil *lubrication* is desirable where an economical means of supplying oil can be used and where slight leakage is not objectionable. Grease lubrication requires a minimum of maintenance attention and can be used if speeds are not too high.



Ball bearing is furnished as integral part of this stamped truss, which might be used in construction of a porch glider. Other stamped components, complete with bearings, are available from the manufacturer, Freeway Washer and Stamping Co. of Cleveland.



Twin Disc Clutch Co.

V-belt sheave and hydraulic coupling are combined in this compact transmission unit. It is designed for mounting directly on shaft of engine or motor. Colored section of Hydro-Sheave is the input side. Grey members are driven by action of the fluid.

Choose Couplings Carefully

Because couplings are so widely used and because they are basically simple in appearance and construction, designers sometimes fail to give careful thought to their selection. Yet, failure to specify the right coupling for the job can undo an otherwise good machine design.

THE TWO BASIC FACTS to remember in coupling application are as follows:

(1) The coupling transmits all power between driving and driven units. Hence it must be capable of handling all peak loads, shocks and sustained overloads encountered in daily service.

(2) With the exception of universal joints, a coupling is not wisely used when it is called on to connect two shafts originally out of line. Its job is to protect against the misalignment that inevitably occurs under operating conditions.

Before selecting a coupling for the machine you are working on, it is well to review the list of types available. The life of the machine and its efficient operation depend on your selection. Unless it can do the required job, even the cheapest coupling will prove to be expensive.

RIGID COUPLINGS are the simplest and cheapest devices for connecting two shafts. But the shafts must be in good alignment to avoid excessive stresses on the coupling, shafts or bearings. Most common rigid coupling is the flange coupling. It has high utility where shafts of different diameter are to be coupled and on shafting at and above 6 in. in diameter.

UNIVERSAL COUPLINGS should be used where the designer has to mount two connecting shafts at an angle or where the shafts are in alignment to begin with but may shift considerably over the life of the machine. A double universal coupling can successfully connect rotating shafts that intersect at angles up to 30 deg. As a general rule, the greater this angle, the lower should be the shaft speed. As will be seen from Fig. 1, the efficiency of the coupling drops off with an increase in the shaft angle. This serves to stress a good design rule – keep shafts in alignment if at all possible.

FLEXIBLE COUPLINGS should not be considered as cure-alls for poor design or manufacture, but rather as correctives for unavoidable misalignment. Perfect alignment often costs much more than a flexible coupling. The flexible coupling, correctly used, compensates for eventual misalignment without adding to the load on either shafting or bearings. It helps shafting and bearings to operate with less strain under unusual shocks and pressures by absorbing a good part of them itself.

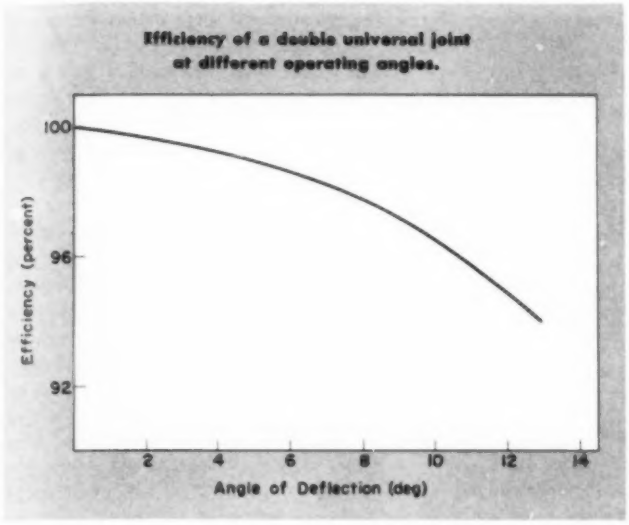
The factors to be considered in the selection of a flexible coupling are as follows:

(a) The nature of the expected misalignment and its extent. Couplings of various designs have flexibility in 4 directions – tangential, angular, radial and axial. Select the coupling that is most flexible in the direction in which misalignment is most likely to occur.

(b) The torque to be transmitted. Do not neglect to multiply calculated torque by the service factor applicable to your type of machine. Where vibration and shock are considerable – as in compressors – the service factor may be as high as 11.

(c) The speed of the shafts and their sizes.

(d) Whether or not the coupling is to be used for reversing service. In this case, select a larger coupling



SERVICE FACTORS FOR FLEXIBLE COUPLINGS

DRIVE	APPLICATION	SERVICE FACTOR
Turbine	Centrifugal pumps, fans	1.25
Turbine	Generators	1.5
Motor	Centrifugal pumps, fans	1.5
Motor	Belt conveyors	2.0
Motor	Duplex and triplex pumps	3.5
Motor	Screw conveyors, hoists	4.0
Motor	Compressors	6.0
Engine	Centrifugal pumps	3.0
Engine	Variable-load generators	5.0
Engine	Triplex and duplex pumps	5-6
Engine	Fans	8
Engine	Compressors	9-11

to withstand frequent reversals. Couplings with considerable backlash should not be used for this application.

HYDRAULIC COUPLINGS actually can replace a group of machine elements because of their many characteristic advantages. One hydraulic coupling can serve as a combination vibration dampener, clutch and protective device. In addition, this type coupling allows engine or motor to develop sufficient rpm at all times for highest torque regardless of load rpm. Because of its many functions, the hydraulic coupling is often a big element in attaining economical machine design.

Factors that will influence the choice of a hydraulic coupling are as follows:

(a) Torque to be transmitted. Output torque is always equal to full input torque. Normal operation at designed load and speed involves slip of 4 or 5 percent, so that power efficiency is 95 percent or better. But torque transmission is always 100 percent.

(b) Power to be transmitted.

(c) Variations in load requirements. A coupling that will be used for frequent picking up of loads will differ from those for constant load applications.

(d) Air temperatures surrounding coupling in service. High temperatures affect power capacity of the coupling.

(e) Shaft alignment. Hydraulic couplings cannot compensate for misalignment.

(f) Most hydraulic couplings are symmetrical. They operate with the power source on either side. Rotation may be in either direction.

ELECTRIC OR MAGNETIC COUPLINGS possess most of the advantages of the hydraulic coupling. In addition, they function as a means of obtaining variable load speeds from a constant speed prime mover. Speed control is effected by varying the excitation current flowing through the field magnets of the coupling. The torque transmitted is directly proportional to the excitation current.

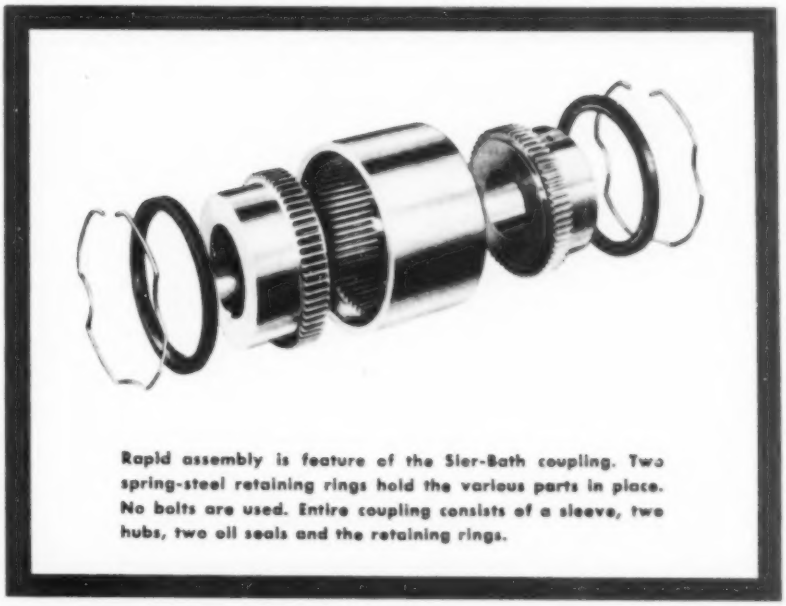
PERMANENT MAGNET COUPLINGS may also serve economically where a non-rigid connection between prime mover and load is desired. The four principal types are:

(a) Eddy current couplings transmit torque in proportion to speed.

(b) Hysteresis couplings transmit constant torque independent of speed.

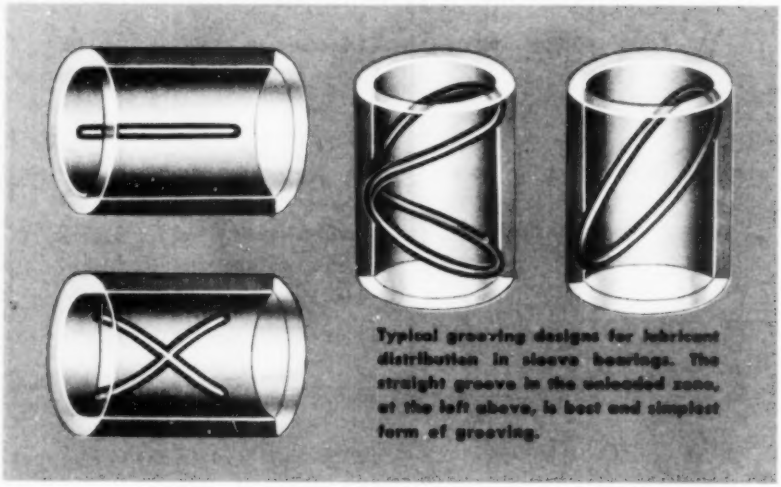
(c) Iron-oil magnetic couplings slip at a predetermined peak torque. They are similar in action to the fluid-electromagnetic clutch but are permanently engaged.

(d) Salient-pole synchronous couplings can transmit torque to a sealed rotor.



Rapid assembly is feature of the Sier-Bath coupling. Two spring-steel retaining rings hold the various parts in place. No bolts are used. Entire coupling consists of a sleeve, two hubs, two oil seals and the retaining rings.

DOLLAR SAVING TIPSHEET ✓ MECHANICAL TRANSMISSIONS



Typical grooving designs for lubricant distribution in sleeve bearings. The straight groove in the unloaded zone, at the left above, is best and simplest form of grooving.

When Specifying

SLEEVE BEARINGS

Consider Cost

MANY TIMES sleeve bearings eliminate the cost of rubber mountings and special silencing devices. The elastic oil film cushions shocks and jars due to gear pounding and misalignment; separates shaft from bearings so that there is no metal on metal wear; dampens out vibration and noise.

In some applications, elaborate seals are not required because flow of lubricant flushes out any dirt that may enter the bearing surfaces.

In general, with fluid film lubrication the load capacity of sleeve bearings increases with speed. Comparatively low cost sleeve bearings with thrust shoulders can take heavy axial loads.

A well designed, installed and lubricated sleeve bearing will last indefinitely. They are not easily destroyed by dirt or corrosion.

From the customers' viewpoint, replacement sleeve bearings are relatively inexpensive and represent less spare parts investment. Also, it is possible to restore worn bearing shells by rebabbitting.

Half-section bearings are obtainable for applications where it is necessary to remove bracket and bearing from the shaft without disturbing adjacent couplings or other components.

Sleeve bearings are not sensitive to imperfections of the bearing surface. Therefore, it is possible for a machinist to make a satisfactory bearing for design experimentation or emergency repair.

. . . Type of Bearing

The machine designer who has decided to use sleeve bearings must consider many factors that will affect the economy of the machine as well as its successful operation. Since it is important that all pertinent factors be taken into account, it is a good practice for designers to seek advice from the bearing manufacturer, who may be able to make beneficial suggestions on individual designs.

The point to be remembered is that despite the apparent simplicity of sleeve bearings, sound engineering rules must be applied in their design, selection and installation. Where this is not done, the result is often a poorly proportioned bearing. Some may be too long, some too short; some with walls that are too heavy, others with walls too thin. Flanged bearings may be used where they are not needed and thrust washers used where a flanged bearing would do better. And, mistakes are costly to the designer.

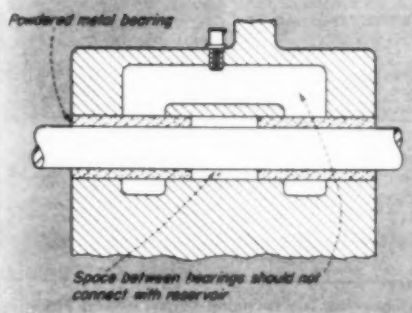
As a rule, for economic reasons the designer should try to use the standard sleeve bearings listed in the manufacturers' catalogs. This is particularly true where his requirements are for small quantities. However, where a user contemplates quantities in the order of 20,000 of a small size bearing, there is probably no cost differential between catalog bearings or special bearings. For the larger bearing sizes, the determining quantity will be lower – possibly 100 or 200. Another advantage of using standard bearings is that they are widely available for replacement.

Length to bore ratio is a limiting factor in the manufacture of sleeve bearings. If the designer insists on long bearings for stiffening shafts, the cost will be high. It will be difficult also to provide proper lubrication and to keep shaft and bearing axes perfectly aligned. Two shorter bearings do the job better and at lower cost.

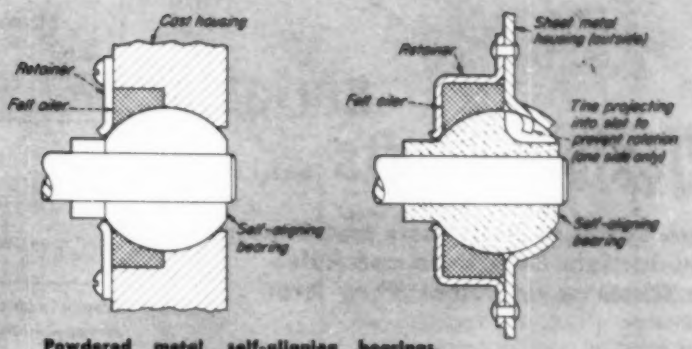
. . . Material

For high speed operation and frequent starting and stopping under load, the use of an alloy having pronounced anti-frictional quality is desirable. However proper consideration must be given to the structural strength of the bearing in terms of applied load and the physical properties of the bearing material.

For long life, a good combination is a hard shaft and a soft bearing material (or vice versa).



Powdered metal bearings require no oil hole. Oil passes directly through the bearing pores. In some cases, design economies are realized by using space between bearings as the oil reservoir.



Powdered metal self-aligning bearings. Where the bearing housings are inherently of an inaccurate nature (some riveted or welded sheet metal housings, for instance), self-aligning bearings of powdered metal or cast bronze are an economical means of preventing improper operation due to misalignment.

Investigate possibility of avoiding need for hardening shaft by proper choice of bearing material. Or, the use of a larger bearing to gain the same end might be economically justified.

If bearing is to be used where it will be subjected to stress reversal (such as in the highly stressed members of an airplane engine), the fatigue strength of the bearing material should be considered.

For dusty atmospheres, the cost of seals and lubricating systems can be cut by selecting the softest bearing material compatible with mechanical strength and resistance to shock loads. Soft material actually absorbs dirt or grit.

For some equipment, it may be economical to specify special bearing alloys. Leaded nickel bronze, for example, is especially resistant to corrosion and is recommended for food processing and packaging machinery. Heat, acids, moisture, dust and vapor affect bearing performance and should be considered in material selection. For a wide range of applications, cast leaded bronze bearings are available with varying anti-friction and load carrying characteristics.

. . . Lubrication

Self-lubricating powdered metal bearings or graphited sleeve bearings are the answer for applications where lubrication is difficult or likely to be neglected.

Many designers use a much too elaborate groove pattern for distributing lubricant through a sleeve bearing. It should be remembered that grooving in the loadad area of the bearing will tend to rupture the oil film needed for proper operation. Many bearings can be run with no grooving at all – simply an oil hole in the unloaded zone. The best form of grooving is a simple straight groove. It is also the most economical.

Seals and enclosures should be supplied on machines that will operate in dusty atmospheres. Or at least, sufficient lubricant flow should be provided to flush out the bearing and keep it clean.

Grease lubrication is the most economical type but is generally limited to slow speeds and heavy loads.

. . . Loading

The actual load capacity of a bearing is determined by both its design and that of surrounding parts in the installation. Good alignment is necessary to insure a proper distribution of load within the bearing. Alignment is affected by shaft and housing deflection, the accumulation of tolerances, and errors in workmanship which can seriously impair the load capacity. The ability of shaft and housing to conduct and dissipate heat developed in the bearing may prove to be a factor limiting load capacity. Surface hardness of the shaft and its degree of finish are important factors in determining the load capacity under conditions of partial lubrication. Finally, the quality of lubricant and adequacy of its supply are of decisive importance in establishing the limiting values of load.

For high temperature applications, the designer has at least three methods of solving the bearing problem open to him. He should consider the relative economies of the following:

1. Provision of fan or oil cooling.
2. Extension of shaft to locate bearings outside the hot zone.
3. Use of bearings suitable for operation at elevated temperatures, e.g., graphited bearings.

In bimetal or trimetal bearings, bearing life is related to babbitt thickness. The anti-friction properties depend wholly on surface action. It is possible therefore to get excellent low cost performance from thinwall steel backed bearings.

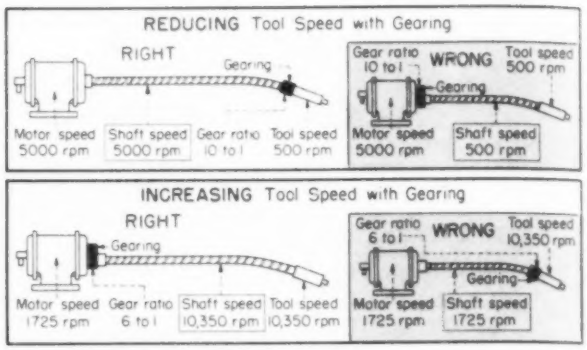
For oscillating shafts, designers can simplify their lubrication problem by use of oil impregnated powdered metal bearings or bushings.

Above data courtesy of The Bunting Brass and Bronze Co.; The Cleveland Graphite Bronze Co.; Bound Brook Oil-Less Bearing Co.; Moraine Products Division of General Motors; Johnson Bronze Co.; The United States Graphite Co.

DOLLAR SAVING TIPSHEET ✓ MECHANICAL TRANSMISSIONS

Flexible Shafts . . .

Can Cut Assembly Costs and Simplify Production. But There are Rules to Observe and Here They Are:



Proper location of gearing for reducing or increasing speed of driven member.

DO

Do plan to use shafting at higher speeds. This will be much easier to accomplish in the design stage. It is easier to relocate your gearing then, than it will be if the design has been finalized.

The limitation of flexible shafting in torque and deflection can be remedied many times by proper application or incorporation of simple gear trains.

Flexible shafting is a power transmission unit and should be used for transmitting power where it is needed.

There are flexible shafts for power jobs and shafts for remote control jobs. It is very unlikely that they can be interchanged.

If possible avoid extremely long lengths. Better results can be obtained by incorporating solid shafts for long straight sections and using the flexible shafting at the turns and bends.

Support long lengths of flexible shafting wherever possible as you would a solid shaft.

Consider using fittings that will give the maximum efficiency and operation. Under most circumstances a floating shaft fitting should be incorporated. This is necessary as the shaft may contract or elongate under loading or flexing.

Check protrusion of shaft fittings outside of the casing to insure that there will be proper engagement with mating parts. Without correct engagement, the shaft may give trouble.

Select a casing that will be the best suited to the particular requirements.

Points such as cost, appearance, service condition, and flexibility should be considered. The casing is a protection unit and should not be more flexible than the shaft.

DON'T

Don't consider shafting an accessory that can be fitted in later on. It should be considered as an integral part of the original design. Compactness and better parts arrangement are typical benefits when flexible shafts are thought of in the design stage.

Don't expect to get a shaft from stock, for 90 percent of the time it will have to be designed for the job. There are shafts that can be selected for your job but the shaft and casing must be cut to your specific lengths and the mating connection must be selected and assembled.

Severe shock loads or overloads that are beyond the capacity of the shafts should not be permitted.

Don't forget direction of rotation. Power drive shafts are designed for rotation in one direction only. Rotation of the shafts in the direction of rotation opposite to that for which the shaft was designed will reduce the torque capacity up to 50 percent. Remote control shafts are designed for rotation in both directions at slow speeds. Deflection rather than torque capacity is a greater factor in this type of shafting.

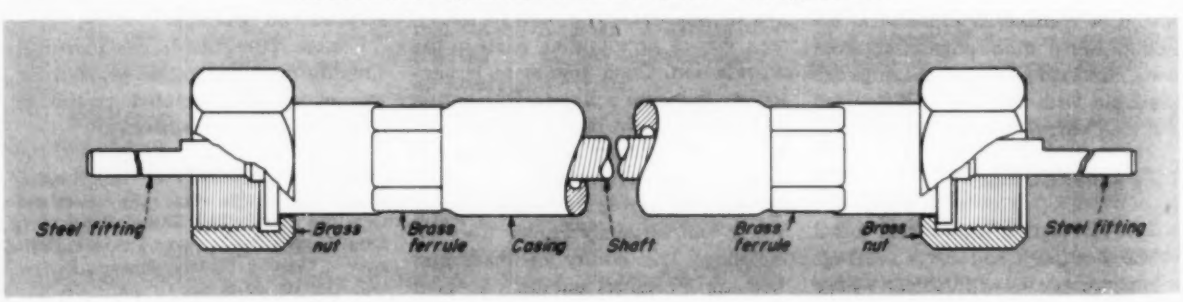
Don't ever bend a flexible shaft or a casing on a radius smaller than the recommended minimum. This may cause a kink or set and ruin the shaft.

Don't, unless absolutely necessary, pack shaft assembly with grease. It adds to the torque load on the shaft. A light coat of grease will be sufficient to give the lubrication needed for good operations.

Don't forget, shafting can be designed to be used under adverse climatic conditions and for rough usage. Heavy duty casings have been designed to protect the shafting for such use. Rubber covered, reinforced casing absorbs the abuse and abrasion that comes with heavy work.

Above contributed by J. J. McManus, Jr., Industrial Division, S. S. White Dental Mfg. Co.

Construction of typical flexible shaft for power drive applications.

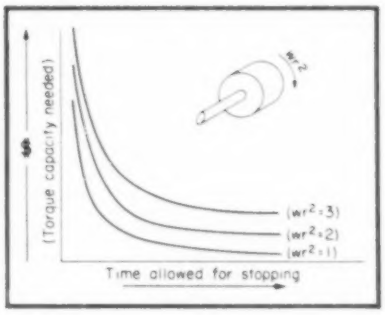


Cost Factors in Brake Selection

THE COST of a stopping brake is related directly to the inertia of the load and, inversely to the time allowed for stopping. This is shown graphically in Fig. 1. Unnecessary "beefing up" of rotating machine members is reflected in brake cost and wear. The same is true if a fast stop is specified when slower braking action could be tolerated. Other factors to be considered in brake selection are listed below.

MECHANICAL BRAKES – the simple mechanically-applied band brake often is all that is needed to stop or hold a load Its cost is considerably less than automatic brakes. While hydraulic, pneumatic or magnetic brakes are most commonly used for high duty cycle machines, especially those that are automatically controlled, a cam-actuated mechanical brake might do the job at lower cost. If the problem is only to hold a load, perhaps a ratchet and pawl will suffice.

COOLING – Is a fan or compressed air system used in the machine? If so, some of the air flow might be tapped for brake cooling. Forced cooling might permit a smaller brake to be used and will certainly lead to longer brake life. Insofar as mechanical brakes are concerned, cone brakes dissipate heat best, with shoe-type brakes next in line. Band brakes run hottest but they have high torque capacity. Multi-disk brakes dissipate heat poorly because of their compact design. But because of this compactness the multi-disk unit should be called for when space is a factor.



BRAKING FORCE – Before specifying a brake, consider the force required to apply it, because braking force costs money in one way or another (e.g., current drain for magnetic brakes). The simple band brake requires the smallest effort. The multiple disk brake is next. The shoe-type brake requires the largest effort.

The fade characteristics of the brake lining must be considered. Since brake ratings normally do not take fade into account, it is poor economy to design up to the limit of theoretical capacity.

Power set brakes – as opposed to spring-set – give good control of stopping. The operator can apply any pressure to get the braking action he wishes. However, power-set brakes can be misused by a careless operator. Brakes subjected continually to excessive torques won't last long.

ENCLOSURES – The type of enclosure or other protection required for a particular application affects cost. A few drops of oil on the brake lining may reduce the torque capacity of a brake by 50 percent. This is true for all lining materials – whether metallic, folded and compressed, or molded blocks. Abrasive dust is another element to be watched. Always, brake cost rises with the degree of protection needed.

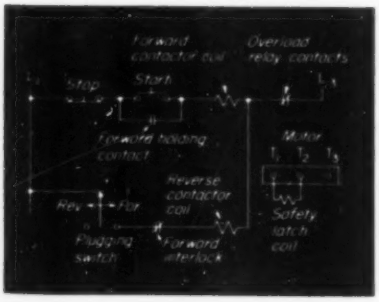
MOTOR DISCONNECTION – Shutting down a motor or engine may be a part of the job of stopping a machine. An interlock switch or automatic clutch often are used to make sure that the prime mover cannot try to drive the machine when the brake is applied. A combination clutch-brake unit may be the most economical solution.

MOTOR DRIVEN MACHINES – Plugging may be the most economical braking method for high duty cycle machines. The stopping effort is produced by reversal of motor torque. Advantages – no frictional wear; equipment required is simple and economical; little maintenance; braking torque unaffected by grease or grit. Make sure the power supply can handle the high plugging currents (about 6 times full load). Also, check motor manufacturer's heating curves to see if the motor selected can withstand braking duty. If the motor is d-c, a combination of dynamic and mechanical braking is the most economical system. The motor supplies about 90 percent of the needed torque and the mechanical brake the remainder. This scheme is suited for high inertia machines that must be stopped frequently.

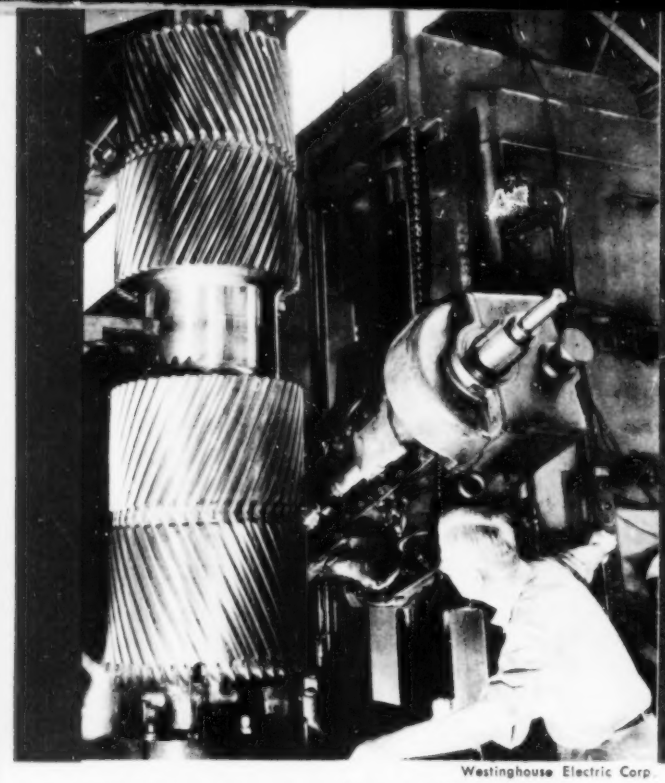
Where a small a-c motor drives a high inertia load, it is still possible to avoid use of friction brakes. For stopping, the a-c supply power is shut off and a small d-c voltage applied across two of the windings, as shown in Fig. 3. This sets up a non-rotating magnetic field that causes a powerful braking action. The stopping shock is great.

Brakes are often used to maintain tension in wire or textile manufacturing. The continuous slippage involved makes brake life short. A hysteresis device may provide all the drag needed – without friction.

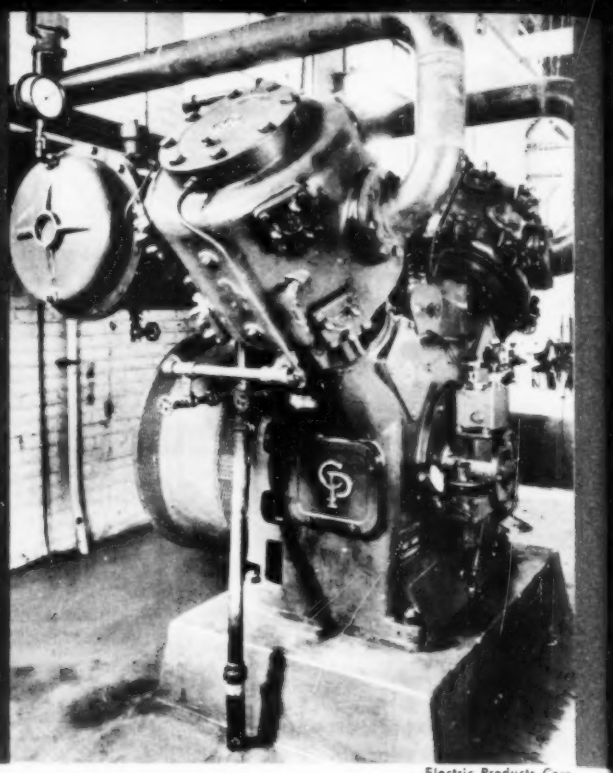
A simple plugging circuit. Pressing the stop button causes the drive motor to reverse its torque and exert a braking effect on the machine. The plugging switch is a centrifugal device that opens the motor circuit just before it stops. Thus, motor cannot drive machine in reverse.



Suggestions courtesy of the General Electric Co., Stearns Magnetic Manufacturing Co., and Wagner Electric Corporation.



Westinghouse Electric Corp.



Electric Products Corp.

Whether your product is like this . . . **or like this . . .**

The Direct Cost of the Product Must Be Analyzed

So MANY FACTORS can affect the cost of producing a part that simply guessing as to what might be the most economical method of construction is inaccurate at best, and may cause the profit margin to be smaller than anticipated or even non-existent. Only a comprehensive cost analysis during the design stage can be relied upon with any degree of certainty.

It is, of course, impossible in one article to detail all of the direct costs that might have to be analyzed for any particular product or method of manufacture. All that can be done is to point out the important aspects that must be considered. However, the direct cost of any product usually can be broken down into about seven groups:

Tooling Cost

Tool cost includes the cost of the tool material, design, manufacture, heat-treating, and an estimated figure to cover breakage, maintenance, and amortization. It is perhaps the logical starting point for a cost analysis.

The tool department should be shown a final detailed and parts drawing of the product as decided upon by engineering. Based on this data, they can then proceed to estimate any and all cost allied with tooling. The estimated engineering and layout time for the tooling must be obtained. The estimated machining and material costs must be added. Finishing – such as polishing of a plastic mold – and heat treating must be accounted for. Not only should this be done for all direct production tooling, but for auxiliary tools, such as inspection gauges and equipment that may be built or bought from outside suppliers. Assembly cost for the tooling, as with a stamping die having carbide or high speed steel inserts at critical wearing points, cannot be ignored. When all of these figures are obtained, all such tooling should be amortized over a period of time, based on the number of parts that can be produced before new tooling is necessary.

After the type of tooling required has been determined, the number of hours required to make it should be estimated and entered in the proper space on a cost analysis form. This time then can be converted into dollars by the tool department. If such tooling is to be bought on the outside, an actual estimate should be obtained from several suppliers.

The engineering and design time necessary to design such tools should be recorded. A rough sketch of such tooling – if it is to be made by the plant – should suffice for estimating the material cost involved. And if any of the tooling must be heat-treated, surface-hardened, electroplated, or mechanically finished or polished, the size and weight of such parts should be determined so that the time required for such operations can be reduced to specific figures.

At the same time, the tool department should furnish a cost estimate

based on the amount of time to set-up the tooling in a production machine. An accurate estimate of the number of parts to be produced within a given time period is imperative if reliable figures are to be obtained. An estimate of the number of parts on a yearly basis is not enough, because if the production rate of the equipment involved is high, and delivery is to be evenly distributed over the course of a year, the tooling may have to be set-up on a machine at least once per month. On the other hand, if production is likely to be seasonal, perhaps only one run or a month's duration may be sufficient to meet yearly demands. Consequently, monthly, bi-monthly, weekly, or even daily production estimates over the base period of a year may be required.

It is then necessary to estimate the life of the tooling, probable breakage in service, and maintenance cost in order to arrive at a practical amortization figure. Here the tool department must rely heavily on past experience – a fact that the designer should recognize and take cognizance of. This amortization figure should next be converted into a part cost.

All of the figures on tool cost then must be entered on a proper form, and overhead costs added.

Direct Production Cost

Regardless of how a part is to be made, the cost of material required to make it must be considered during an early stage. For this step, then, it is necessary to estimate the actual weight of the material in the part, make allowance for the amount of scrap and defective parts that are likely to be produced, and determine the actual material cost on a piece basis or on the basis of a large number of pieces. If the product is an assembly, the individual items must be analyzed. If it is a complex part, it can be divided into a number of geometrical solids and the weight of each of these totaled.

Next, the hourly production rate of the machine or equipment that will be used to make the part must be established. Here the time study and methods departments will be of help in providing data and in estimating what percentage of the actual production rate can safely be allowed. If the product is an assembly rather than one item, such as a forging, the hourly production rates for all component parts must be obtained. If dimensions of the part are critical and inspection must be 100 percent, the time involved in this operation must be estimated.

Frequently subsequent operations are necessary. The part must be heat-treated, machined after heat-treating, and perhaps even burnished prior to heat-treatment. Or it may be a plastic molding, in which case it would have to be cleaned and perhaps drilled or punched. All the steps in production must be listed, an estimated time allowance established, and the direct labor figures converted into dollars. Consideration also must be given to salvage operations, and to overhead costs in the production department.

Assembly Cost

Often, if the product is a part that can be made by one process, assembly costs do not enter into the cost analysis. More often it does.

Assembly may take various forms. The parts may be bolted together or fastened by quick acting snap or screw fasteners. They may be welded, or riveted, or brazed. A shrink fit may be involved, or a complex assembly operation such as a compound planetary gear. The product may be simple, like a brazed heat exchanger; or it may be extremely involved, like a machine tool or large household appliance, and necessitate wiring, fastening and hand fittings.

The time of each of the operations in the assembly should be estimated and totaled, after which the cost figures can be filled in. Assembly fixtures should have been taken into account in figuring tooling cost, but the testing or inspection of the product as it leaves the assembly floor should be added. Again, overhead cost must be added to the total.

Finishing Cost

Like assembly costs, finishing costs may or may not be a part of the production expense. Whether they are or whether they are not may be the determining factor in selecting one production method over another. A stamped and brazed assembly, for example, may have to be painted prior to shipment, but if the same assembly were made of plastic parts, the finishing operation likely could be ignored, since plastics often can be molded in any of several colors or even in two or more colors. Of course, other factors enter into the selection of the process.

In figuring finishing cost, again the number of operations should be computed, a time factor estimated for each, and all material costs and overhead.

Packaging and Shipping Affects Final Cost

The shipping cost usually is based on the weight and bulk of the product. Packaging cost is based on the type of container used, whether one or more parts can be packed in one container, and on the type and quantity of other materials used. Past experience on similar products may be relied upon to furnish the necessary figures, or the estimated cost may be based on a careful analysis by the shipping department. At any rate, overhead and damage in shipment should be taken into account, especially since damage claims against a carrier require a considerable amount of checking and bookkeeping.

Overhead Cost and Profit

Finally, the addition of a per unit or a per thousand unit burden must be added to the product cost in arriving at a total estimated production cost. Unfortunately, only the accounting department usually is in a position to supply such information, and the data may not be too accurate if the product is a new one or is radically different from any that has been made before. This overhead consists mainly of fixed plant charges and of fixed charges for non-productive personnel. If all of these cost factors were considered during the design stage, it is obvious that the engineering department would be on a sounder basis when recommending production methods for products under development, when recommending design changes to management, and when competing in a price conscious market. It is surprising that not every concern operates on such a basis.

Comparing manufacturing methods or different types of product parts on the basis of direct costs alone is not enough. Intangibles may change the cost picture entirely.

Beware of the Cost of . . .

INTANGIBLES

Cost Estimates

The usual practice in cost estimating is to include the sum of labor, material, tooling and general overhead. The cost of operating the purchasing department and the stores system is usually added, as a percentage, to the delivered price of the materials used. Shop handling costs are sometimes included as a percentage of the shop costs. Similarly the cost of the operation of the engineering department is incorporated as overhead, appearing as a percentage of some figure or another.

For general accounting purposes the above method of costing seems to be satisfactory. To a large extent, the plusses and minuses just about balance out over a long period and as long as the totals agree everybody is happy. Unfortunately, such cost accounting does not reveal on the books the possible leaks in the form of costs that are chargeable specifically to certain classes of items and not at all to other types of items.

Handling and Storing

The cost of handling and storing the heavy and bulky items such as castings is obviously many times the cost of handling a comparable dollar volume of small expensive parts such as ball bearings. The same applies to the relative cost of purchasing. Hence, in a plant that estimates the cost of purchasing and storing on a percentage of the cost of the item, an exact analysis will reveal that the high priced light weight items are being charged more than their share of the actual costs involved. This same relationship appears again and again when attempting to arrive at the actual cost estimate as against general accounting figures.

New Designs

From the very beginning of a new design, while the papers are still on the drawing board, the intangibles start creeping in. As the design progresses and the manufacturing processes develop, the intangibles grow. The actual costs relating to individual items are allocated on a percentage basis until finally the total allocation to an individual item bears no relation to the true costs involved.

Every individual drawing accumulates its own train of intangible expenses. After final approval of the drawing, copies are sent to an approved list of individuals. The greater the number of different parts in the finished product, the greater the number of drawings that must be made and correspondingly the greater the number of prints issued.

Paper Shuffling

An expression often used in the office and engineering department says, "paper is cheap." Scant attention is given to requests or requisitions for additional engineering prints. Once a list of those to whom prints should be sent automatically has been established, the names listed continue to receive the prints even after their need for them has long vanished. When the chief engineer of a nationally known motor manufacturer took the time to have the lists of print recipients thoroughly checked he was astounded at the results. There were many names that could just as well get along without certain prints and those names were immediately deleted. The following year the cost of printing paper used by this company was reduced from $80,000 to $50,000. The saving of $30,000 in printing paper alone represented 0.15 percent of the total sales of the company. To this saving should rightly be added the further associated savings in the labor of making the prints, keeping the prints, and the messenger service for their distribution. Finally, there should also be added the cost of paper shuffling and the waste of time of those who received the prints but had no real need for them.

Fewer Parts

Corresponding savings result when the number of parts of the product are reduced. If the total number of pieces involved are reduced ten percent as a result of design simplification and standardization, obviously the number of prints required will be reduced correspondingly. This is only the beginning of the savings that accrue when a smaller number of parts are required. The cost of purchasing and stores is likewise reduced. Correspondingly fewer purchase requisitions, inquiries, correspondence with vendors, purchase orders, invoices and billings, stores handling, stores records and all related cost factors are reduced. All such savings should be credited to standardization and simplification.

Product Simplification

In many instances it is possible to simplify the design and correspondingly reduce costs by developing the design so that completely assembled components can be purchased instead of unit parts which must later be as-

sembled in the shop. Even though the total cost of unit parts plus their proccessing and assembly might appear to be appreciably less than the purchase of the completely assembled component, in many instances the actual cost will be greater. The actual cost of purchasing the many individual parts, storing them, handling them, the inventory costs of capital investment, insurance, and similar factors may greatly exceed any apparent difference in the assumed costs.

By reducing the number of different parts in the product a saving also accrues from purchasing in larger lots. This has the effect of not only lowering unit price, but also reducing the dollar value of materials in stores, plus all other intangible savings. Especially when the standardization covers a number of sizes and models the actual cost reductions become highly significant. Admittedly, it is difficult to evaluate exactly the sum total of all the intangible savings for each item. It is possible, however, to arrive at some kind of a rough figure which might serve as a guide.

The engineering department of a medium sized manufacturer developed a line of speed reducing units. About a dozen models were required to round out the line. Before actual design was begun a long study was made. In spite of the fact that this company has a foundry they decided that the best and most economical design would be a welded construction. Tentative designs were then made to form the basis of a searching cost analysis. By exercising ingenuity it was found that a dozen models could be produced as welded constructions from a relatively few different thicknesses of steel plates of given widths and lengths. Thus a relatively small inventory of steel plate was sufficient to fill an order for a given number of units of any or all models. The dollar value of the inventory was naturally correspondingly small, the purchasing and stores costs were reduced and there was the intangible, but vital, advantage of being able to make deliveries of the finished product much quicker. This same procedure, applied to an already existing line of products, can well make the cost of an extensive redesign program worthwhile. When adding up the cost of a product, never neglect the cost of purchasing, storage, handling, and the other often-forgotten, but always important intangibles.

Shop Transportation

When a manufacturer reduced the weight of the heaviest item in his line of products from 103 pounds to 32 pounds by changing the material to aluminum, the resulting unsuspected cost savings became glaringly obvious. It was no longer necessary to wait for a shop truck to transfer the casting to the next machine tool. It was not necessary to have air hoists plus the service of a helper to set the pieces into the machine tool. The time normally lost by the machine operator waiting for someone to help him to set up the pieces was wiped out. Those total savings alone amounted to several times the difference in cost of the metal. In addition, the cost of packaging and delivering the finished product to the customer was less.

Shipping Costs

Although the cost of shipping the finished product to the customer is often entirely overlooked in the engineering department, actually this cost is an extremely important item. The *real cost of the product to the customer is the price that he must pay to have it delivered where he wants it.* Thus the difference in freight charges might well determine which manufacturer will get the order.

Product Improvement

If the customer is willing to pay for an added special feature an amount that is greater than the cost of incorporating the feature in the product, the improvement will pay off. Sometimes this factor is easy to judge. In production machinery the greater output resulting from an improvement can readily be evaluated in dollars and cents. Lower cost maintenance and upkeep can be established to a fair degree of accuracy. But many other features are difficult to evaluate. Quieter operation, added safety features, easier handling, smaller size, lighter weight and many other such features possess widely varying values among different kinds of products. Appearance and color is the most nebulous factor to attempt to evaluate. Unquestionably a distinctive appearance that bespeaks quality, functional efficiency and stimulates pride of ownership cannot possibly be expressed in dollars and cents.

It is not entirely within the province of the design engineer to attempt to evaluate appearance and color. However, he must always be cognizant of this highly important factor and must always keep in close touch with the "Pulse of the Market" and be ready to aim his efforts accordingly. And he should have available at least the results of market surveys and research studies and perhaps also the services of an industrial designer.

Final Design

It cannot be overemphasized that in so far as possible the *design that the engineering department originally puts into the shop shall be the final design.* Any changes after manufacturing has begun should be held to simple and elementary ones. The disruption and confusion created by major design changes made during production are often extremely costly. Accurate production records reveal this. Ironically the largest cost is not that resulting from scrapping of semi-finished and finished parts, but is rather the cost of teaching the shop personnel all over again with reference to the manufacture and assembly of the product. Obviously a change that creates a bottleneck in the production of any part or subassembly will correspondingly reduce the production of finished units. Thus the cost of any improvement made after production has gotten into full swing can be completely out of line with its value. If the change was made for the purpose of cutting costs, the total actual cost savings might well be only a fraction of the losses incurred during the shop learning period when the change was introduced. This emphasizes the great importance of a complete cost analysis during the progress of the design, during which progress every effort should be made to develop the simplest design commensurate with required sales values.

DOLLAR SAVING TIPSHEET ✓ TYPES OF CONSTRUCTIONS

Metal Powder Parts— Selection Factors

As COMPARED with other processes, powder metallurgy involves relatively high raw-material cost; sand casting is an illustration of a low material cost process. However, there is virtually no material wasted in the powder process, while in sand casting it is an outstanding disadvantage. Tool costs for powder operations are among the highest.

Production lot sizes may be small with sand castings, but must be large with zinc die casting, drop forging and powder metallurgy because of die costs.

With powder metallurgy tolerances of plus or minus 0.0005 in. are attainable on special production jobs and plus or minus 0.001 in. on regular production jobs. Die casting and stamping are accurate to plus or minus 0.001 in. depending on part dimensions.

DESIGN CHECK LIST

The following limiting factors, some of which are interrelated, apply to all powder metallurgy parts.

Production

Minimum quantity: 5,000 to 10,000 (50,000 usual average).

Production speed: 200 to 1,000 per hr; 200 to 300 per min on very large quantities of simple design.

Tolerances: ±0.002 in. common in unsized parts; ±0.0005 in, or less possible in sized or coined parts.

Die cost: From 100 to 2,000 dollars or more, depending on complexity; customer usually pays for dies.

Materials

Ferrous

Iron or iron-carbon
Iron + infiltrant or impregnant* – copper, brass or bronze
Steels
  common alloy
  stainless
  heat resistant

*Infiltrating or impregnating is a new technique in which the sintered piece is placed in the furnace again, with a slug of copper or copper alloy on it. The copper melts, infiltrating into the pores of the piece. This is claimed to be a relatively low cost (eliminating sizing operations) method of increasing density and physical properties.

Nonferrous

Brass – pre-alloyed
Bronze – mixed or pre-alloyed
Nickel silver
Copper
Aluminum
Magnesium
Brass + iron

Special materials: Tungsten and other high melting point materials; metal-ceramic mixes.

Properties

Tensile (uncoined test bars):
  Ferrous – 12,000 to 45,000 psi
  Infiltrated ferrous – over 75,000 psi possible
  Nonferrous – 30,000 to 50,000 psi

Hardness (uncoined test bars):
  Ferrous – 40 to 140 BHN
  Nonferrous – 35 to 60 BHN

If needed, tensile and hardness properties can be increased by coining. *Density and Porosity*: Density varies directly, and porosity inversely with compacting pressure. By infiltrating, 100 percent density can be achieved if needed. Porosity (hence lower pressure) is desirable in oilless type bearings or where subsequent infiltrating is desired.

Design Precautions

Undercuts, re-entrant angles, grooves cannot be obtained, except if the groove runs the entire length of the piece, and in the same direction as the travel of the punch (see Fig. 1).

Shapes that require feather edges, narrow and deep splines should be avoided (see Fig. 2). Since molding dies are frequently subject to pressures up to 100,000 psi, shapes that require a die of weak design should also be avoided.

Lack of flow in compacting means that metal powders must be placed in the die in the relative final molded location, and thin projections in the lateral plane should be avoided (see Fig. 2).

Ratio of depth to diameter should usually be held to a maximum of 2.5:1, but under special conditions can be as high as 5:1. In cylindrical parts, for a wall thickness of 0.062 in. a length of 1¾ in. is the maximum.

Thin walls should be avoided; 0.030 in. is the minimum wall thickness.

Sharp edges or corners should be avoided. All molded parts should be made with edges beveled, and with fillets on internal angles. Such bevels and fillets should have a 0.010 to 0.015 in. min. radius.

Inserts are not normally molded into metal powder parts.

Section variations should be held to a minimum, and should not be abrupt (see Fig. 3).

Finishing

Powdered metal parts can be machined or ground, to maintain closer tolerances, using the same machining procedures as on cast metals. Normal parts can be finished with most organic and inorganic coatings. Plating requires an additional rinsing procedure, to get rid of acids. This is somewhat more expensive, but is an established process.

EDITOR'S NOTE: This article is based on information supplied by The New Jersey Zinc Company and Wel-Met Company.

Fig. 1—Involute gear tooth is a typical part ideally suited to powder metallurgy fabrication. This is impossible to hob because of profile undercut.

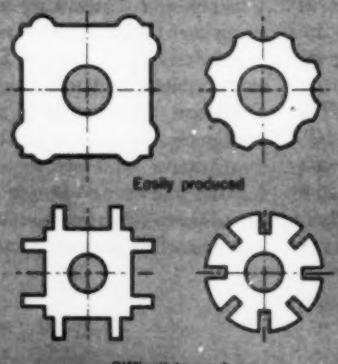


Fig. 2—Deep splines and narrow projections should be avoided because metal powders do not flow.

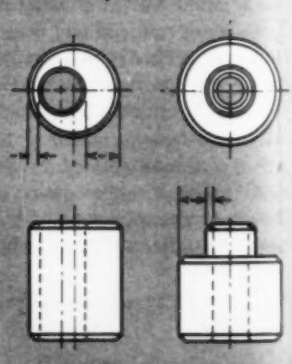


Fig. 3—Parts embodying great differences in section size are usually difficult to produce.

Points to Watch When Designing Spun Parts

As COMPARED with stamping, the spinning method has been found to be most economical where a limited number of parts are to be manufactured. The curves in Fig. 1 illustrate the comparative costs in making basic machine parts. The high cost of stamping dies, makes the spinning of a large number of parts more economical. From this chart, the dividing line between the spinning and stamping method of the parts shown would be approximately 1,000 pieces. When the parts are larger or more complex, a greater number of spun parts can be made more cheaply than if they were stamped.

Thin cylinders, lids, domes and circular deflectors ranging from ¼ in. to 10 ft in diameter are examples of parts that best lend themselves to spinning. Almost all metals can be used in the spinning process. Some are particularly ductile, while others tend to work-harden and require annealing when large deformations are made. The maximum thickness that can be spun depends largely on the material, size, and shape of the part. In general, sheet aluminum can be spun up to ¼ in. thick, low carbon steel up to 3/16 in. thick, and stainless steel up to 1/16 in. sheet.

Tolerances can be held to 1/64 in. for small pieces, up to 1/16 in. for large ones. In special cases, a tolerance of ±0.005 can be spun; however, this requires a metal spinning form and special skill which makes it more expensive. Since there is always a slight amount of springback in the spinning process, it is more practical to make allowances for this than to attempt to eliminate it.

Design factors in Fig. 2 are:

(A) Keep the radii above 4x thickness. This reduces metal strain and makes a smoother appearing piece.

(B) Use outside rim, flange or bead – such a shape can be made on same form and so eliminates a special form and set-up when rim is inside.

(C) Use larger tolerances wherever possible – with a tolerance of ±1/16, special effort can be avoided.

(D) Allow for slight variations in flatness of flange or rim – this makes another operation unnecessary.

(E) For long cylindrical parts include a taper to easily remove part from form. When using a wood form, allow 3/8 to ½ in. per ft. taper; for a steel form, allow 1/32 in. per foot.

(F) In spinning, metal tends to become thin at the bends. For greater strength at certain locations metal can be made to flow to increase thickness.

FIG. 1

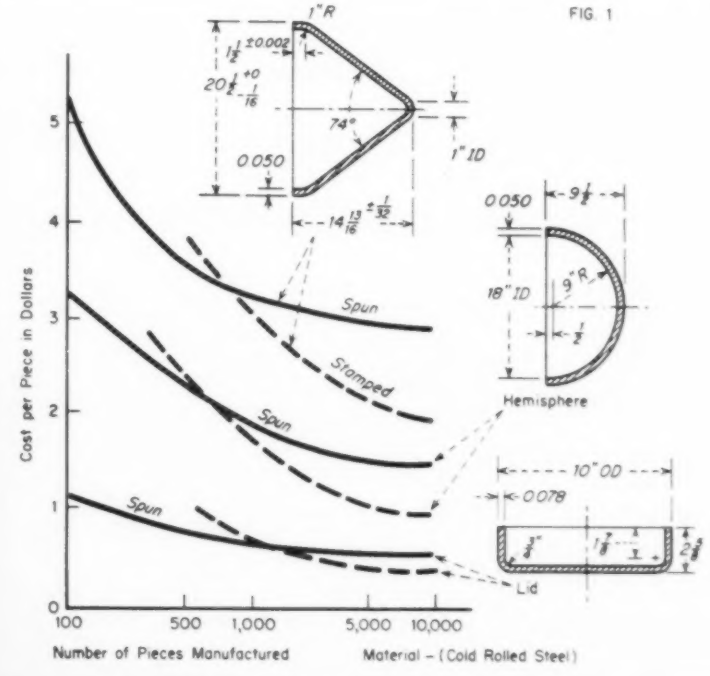
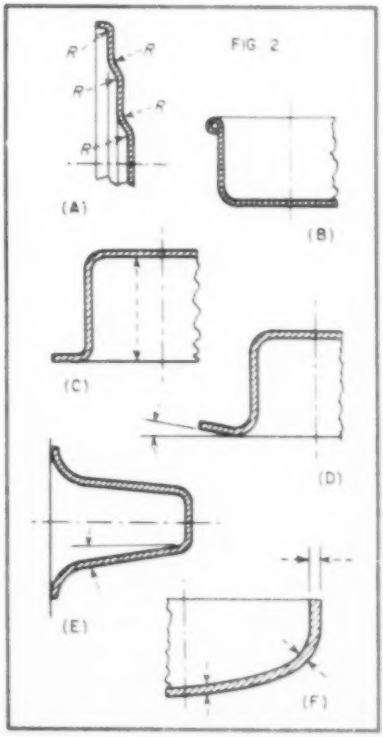


FIG. 2



DOLLAR SAVING TIPSHEET ✓ TYPES OF CONSTRUCTIONS

When To Use Impact Extrusions

MANY PARTS ordinarily designed for drawing, spinning or turning can often be altered to take advantage of the impact extrusion process. At present, the production of rigid shells by impact extrusion is economically feasible only with aluminum or with zinc.

Impact extrusions are cup-shaped parts having cold-forged bottoms combined with extruded sidewalls. In forming a shell or part by this process, a relatively thick disk or slug is placed in a die and struck by a punch. The impact is of sufficient intensity to cause the metal to flow upward through the clearance space between the punch and die.

COST FACTORS. The cost of extrusion tooling is usually considerably less than that of tools used in drawing. This is especially true where the shell is long enough to require several drawing operations; with impact extrusion such a shell is formed in one operation and with one set of tools.

The nature of the extrusion process makes it possible to produce shells with relatively sharp bottom outside corners. Internal fillets are formed automatically, adding reinforcement at this point. In addition, the severe cold-working the metal receives sharply increases stiffness of the whole shell.

Many shells of irregular shape or with tapered or curved sidewalls cannot be made by this process. However, the straight sided shell can be made with many modifications that can be produced only by impact extrusion. These include heavy bottoms with bosses, lugs, rivets, stems, necks, indentations or embossings (Figs. 1 and 2). Another advantage of this process is the possibility of variable wall thickness. As shown in Fig. 3, this often permits a desirable decorative effect or can be useful in a purely mechanical way.

DESIGN CHECKLIST FOR ALUMINUM IMPACT EXTRUSIONS

1. What revisions will be considered to permit adaptation to extrusion process?
2. Aluminum impact extrusions are commonly available in the following alloys. Indicate preference: 2S_____; 3S_____; 61S_____; A51S_____ Comments:_____
3. What are physical property requirements?
   Strength:_____ Electrical:_____
   Corrosion:_____ Thermal:_____
4. What are critical dimensions of design?
   Inside Diameter_____ Inside Length_____
   Outside Diameter_____ Outside Length_____
   Bottom Thickness_____ Wall thickness_____
   Specifications of lugs or bosses_____
   Rib detail, if any_____
   Secondary forming, beading, piercing, etc_____
5. If pressure container, specify operating pressure requirement:_____psi
   Test pressure requirement:_____psi
6. What are surface finish requirements?
   Inside surface_____
   Outside surface_____
7. If further finishing of basic extrusion is contemplated, what methods will be used?
   Machined_____
   Ground (Satin Finish)_____ Formed_____
   Etched_____ Scratch Brushed_____
   Alumilited_____ Buffed or Polished_____
   Special_____ Painted_____
8. Is extrusion for packaging purposes?_____
   If so, what type materials?_____
9. What are anticipated yearly requirements?_____
10. What is probable quantity per run?_____

The above design check list for aluminum impact extrusions has been furnished by M. A. Fair, Assistant Manager, Edgewater Works, Aluminum Company of America.

Fig. 1 Left — Heavy bottom with a thin sidewall is "natural" impact extrusion.

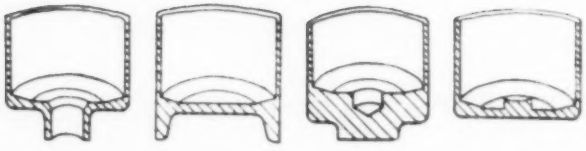


Fig. 2 Above — Bottom design including bosses, hollow or solid studs, necks, plug caps or cavities on the inside or outside of shell.

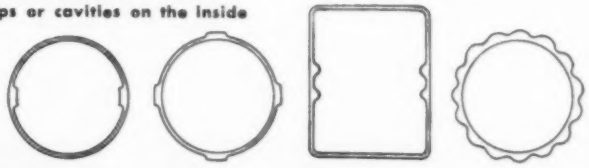


Fig. 3 Below — Wall design of varying thickness in cross-section, or with longitudinal internal or external ribs.

Precision Investment Castings

1. Economic and Design Factors

Considerations in the selection of investment castings:

(a) Cost of part as produced by other methods such as stamping, forging, die casting, impact extrusion, screw machine, etc.

(b) Tooling costs per unit of quantity required if produced by other methods.

(c) Low cost of material lost in metal scrap.

(d) Gain in metallurgical soundness; such as freedom from stresses and from differences in strength that result from grain orientation.

(e) Improved service or engineering performance obtained by using a metal or alloy that can be investment cast to acceptable tolerances, but would be difficult to machine or form by other methods.

(f) Desired shape, contours, and dimensional accuracy can be readily obtained.

(g) Simplification of design and production operations through combination of a number of units into a single investment casting.

(h) Reduction in assembly costs through use of a casting of complicated shape.

(i) Other design possibilities and material properties not otherwise obtainable.

2. Alloys for Precision Investment Castings

The range of alloy selection is almost unlimited. All metals, except the aluminum nickel cobalt alloys, that can be melted can be investment cast. When investment castings are not to be machined, machinability is not a factor in the selection of an alloy. Materials should be selected to satisfy physical, chemical, electrical and metallurgical requirements. If possible, take advantage of a casting price, by selecting an alloy that the foundry is prepared to produce readily.

3. Check Design

Heavy sections should not be joined to light sections. Webbed designs are stronger.

Complicated cored passages are used only where necessary.

Draft is not always required, but most founders prefer at least $\frac{1}{2}$ deg. per side to minimize the difficulty of removing, without distortion, the wax pattern from the mold or die in which it is formed. Draft is desirable whenever it does not conflict with design requirements or interfere with space considerations.

Wall thicknesses as cast should be greater than the following minimums;

Large section areas	0.050 in.
Tapered walls	0.030 in.
Edge thickness	0.012 to 0.015 in.

Fillets are used at corners. Fillets should not be smaller than $\frac{1}{32}$ in., $\frac{1}{16}$ to $\frac{1}{8}$ in. is preferred. Since fillets strengthen the casting, they should be used even when subsequently squared in machining.

Faces that must be free from all defects and those faces that can have minor marks should be so indicated. Flat areas are difficult to cast free from imperfections.

Cored holes should be provided in heavy sections to aid in reducing shrinkage difficulties.

Small holes are difficult to cast. For high melting temperature metals, hole diameters should not be less than 0.050 in.; for low melting temperature nonferrous alloys, hole diameters should not be less than 0.020 in.

Blind holes should have a depth not greater than twice their diameter.

Radii at root of cast threads and serrations should be not less than 0.005 in. Internal cast threads are expensive.

Metal should be provided for reaming cast holes that are to be threaded for tapping.

Tolerances should be specified. Average tolerances for high melting temperature metals is 0.005 in. per in. For sections less than 0.6 in., a tolerance of 0.003 in. per in. can be held. Average tolerance for low melting temperature nonferrous alloys is 0.002 in. per in. Removal of gates, sprues, and wax parting lines by grinding does not permit tolerances closer than 0.010 in. at ground areas. Liberal tolerances reduce the cost of producing castings and result in stronger parts.

DOLLAR SAVING TIPSHEET ✓ TYPES OF CONSTRUCTIONS

You Can Obtain Additional Benefits from the Process if you

Check These Points When Designing a Die Casting

Although many of the broad aspects of designing for die casting have been thoroughly covered in the technical literature, some of the less obvious but economically important points have not been touched upon. Following are some tips from the design, production, and metallurgical departments of the Doehler-Jarvis Corporation.

✓ Successful dies have been designed and presently are in production which are adjustable for different lengths and widths of parts. If a number of similarly shaped parts whose length and width differ to some extent are to be made, such dies may well be the solution for economical production.

✓ Many small parts of the same shape can be cast in one die – a multiple impression die; multiple impression dies having up to 48 cavities are currently being used. If parts have dissimilar contours, they can be cast in a combination die, which also is a multiple cavity type; examples of parts are right and left hand brackets and covers and cases for an assembly.

✓ If parts are small and subject to periodic design changes, considerable economy can be effected by use of unit dies, in which the actual die cavity is an inserted block in the die base. Unit dies of 4, 8, and 16 impressions – the inserted impresisons not necessarily being for the same shaped part – are practical and economical for small lot production. The greater the number of cavities in the die, the greater the productivity in parts per hour and hence the lower the labor cost.

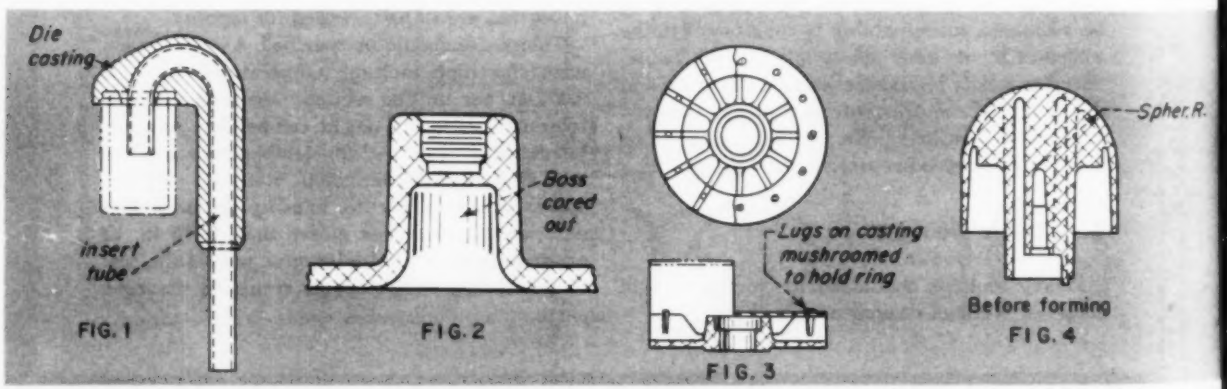
✓ Contours that make the die expensive are those that cannot be produced through the rotation or traverse of machine tools. Expensive repairs are avoided by designs that can be made in dies without delicate parts, extensive coring, or loose pieces.

✓ Designs that call for cores to extend across the parting line of the part should be avoided, as differences in thermal expansion and other factors may cause misalignment in holes through which the core is to pass.

✓ Intricate coring can sometimes better be accomplished by preformed inserts, such as coiled tubes or reverse tube bends, Fig. 1, than by a complex coring mechanism in the die.

✓ Intricate coring of holes, slots, and recesses can be easily accomplished. Coring of parts may eliminate subsequent machining operations or may make possible the production of parts that would normally be difficult.

✓ An internal undercut can be cast by loose die pieces that are ejected with the casting after each shot, but assembly of the pieces in the die prior to each casting cycle takes time and slows up the casting shot. However, this still may be more economical than a subsequent machining operation.



✔ A shroud at the parting line of a casting having complex contours saves money in the trimming operation, since the trimming die becomes less intricate, costly, and difficult to maintain.

✔ If the casting is designed so that the flash can be trimmed against the main body, less difficulty is experienced in the trimming operation due to the raising of burrs or breaking out of the adjacent wall.

✔ Keeping the parting line in one plane not only simplifies the construction of the die casting die, but also of the trimming die.

✔ Cored holes usually contain a flash or fin that usually is removed by a subsequent punching operation. If sufficient taper is provided in the hole, the hole itself can be used as the punching die.

✔ If holes must be formed in thin sections of casting, often it is more economical to punch them rather than to cast them; the thicknesses of metal and the diameter of holes that can be punched are governed by the same standards as for sheet metal. This also is frequently true of drilled holes.

✔ Use of a recessed fillet when sharp corners are required for ease of assembly minimizes shrinkage stresses and possible breakage were the edge to be made sharp.

✔ Ribs and generous radii – $\frac{1}{8}$ to $\frac{1}{4}$ in. – add to the strength and stiffness of die cast parts, and often eliminate distortion that might otherwise occur when the part cools and is ejected.

✔ Besides use as bearing points, bosses and projections can be applied to increase strength and stiffness, to act as locating points for subsequent machining or assembly operations, to act as spacers, to serve as ejection points, or to equalize stresses. If bosses are heavy, Fig. 2, they can be cored part way to save metal and prevent porosity and stress concentrations. Also, inserts placed in the metal of heavy bosses prevent porosity.

✔ Integral studs and projections often can be riveted, staked, or spun over, Fig. 3, to hold an assembled part. This obviously is only feasible with highly ductile materials such as zinc and some of the aluminum alloys.

✔ For intricate castings, it sometimes is more practical to make the casting in sections, and then use one as an insert when producing the other.

✔ External threads usually should be chased instead of cast if (1) the pitch is greater than 24 threads per inch for zinc, aluminum and magnesium, 16 threads per inch for copper alloys, and 32 threads per inch for lead and tin alloys; or (2) a precision fit is required.

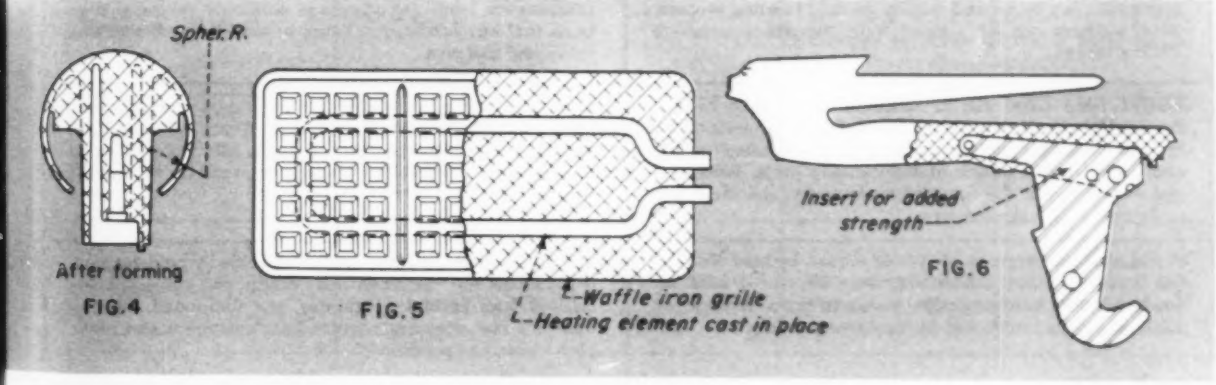
✔ Some parts can be cast flat and formed into shape in a subsequent operation. For example, a hollow section cast as a *U* can later be formed into a spherical shape, Fig. 4. Or an impellor with cup-shaped paddles attached at various angles to the hub can be cast with all paddles in the same plane, and after casting the paddles can be twisted into the required position.

✔ Zinc, tin and lead, being the alloys with the lowest melting point, require die materials less critical than some of the higher melting point alloys – such as copper. Die life also is longer with these alloys, and as a result, the tooling cost, which may be high, can be amortized over a greater number of parts.

✔ Aluminum die castings can be resistance welded without difficulty, and many of the copper alloys can be joined by furnace or resistance brazing. Production of a product in two or more sections thus may be more economical than casting it as a single unit. Also, tin or lead castings can frequently be soldered to form an economical assembly.

✔ If the casting is to be subject to high fluid pressures in service, special treatment of the casting or use of an inserted passageway will prevent leakage and may improve the ease with which the casting can be produced.

✔ Use inserts to impart to the metal, properties that it may not possess, Figs. 5 and 6, to provide means for joining the casting to other mating parts during assembly, or to simplify the design of the casting by replacing certain complicated sections by fabricated parts.



DOLLAR SAVING TIPSHEET ✓ TYPES OF CONSTRUCTIONS

The Place for Cold Headed Parts

Courtesy of Russell, Burdsall & Ward Bolt and Nut Company

THE COLD HEADING process is practical for the production of bolts, machine screws, special fasteners, small cams and pinions and other small mechanical parts. When contours are relatively simple, it is economically competitive with screw machine production. Economies result when parts are made on a mass-production basis so that tooling costs are justified. For bolts, 15,000 units are an average economical run; 50,000 or more are recommended for machine screws.

The fatigue and shock resistance of both ferrous and non-ferrous materials can be increased, and scrap losses can be reduced, especially on small, externally threaded parts like bolts, screws and link rods. Scrap rates vary from 0 to 5 percent, rivets typifying pieces in which all stock is utilized. For internally threaded parts like nuts, scrap rates average 18 percent, using latest techniques.

ADVANTAGES AND LIMITATIONS	FACTORS AFFECTING COST
Most metals can be cold headed although some of the stainless steels and aluminum alloys require preliminary annealing or spheroidizing. Plain carbon steel, alloy steel, low-lead brass, silicon-bronze and Monel can be cold headed. Magnesium is not practical as yet.	The cost of complex steel parts is lowest with low carbon steels. High carbon and alloy materials are harder to work and shorten life of dies, slow speed of heading operations. If carbon is in 0.25 to 0.45 range, the steel must be spheroidized prior to heading. Below 0.25, no such operation is required.
Shoulders can be made anywhere along the shank. The shape of upsets can be varied from simple concentric circular or oval sections to squares, hexagons, diamonds and toothed profiles. Cams having a limited amount of offset are also possible.	Thin, large-diameter upsets and the complicated section shapes are more costly to form. Scrap rates increase, and die wear may become excessive, especially if the metal is materially work hardened during the final blows of the punch.
Parts made from stock having an original cross section of one inch or less can be economically formed. Upsets having 26 times the final shank diameter are possible. Length of parts is generally limited to about 8 in., although pieces up to 6 ft. long can be upset at one or both ends in a rod header.	Stepped contours or eccentric upsets increase die costs and slow speed of forming. When long, slender pieces are called for, consider substitution of larger diameter section formed from a milder grade of steel. The added cost of heat treatment to prevent distortion can thus be obviated.
In addition to rolling coarse, fine or lag threads, special operations can be formed during the cold heading process. Star washers can be slipped onto the shank prior to rolling threads.	For threaded parts, use standard sizes and accepted specifications for length of shanks to eliminate special operations that cut production rates, in addition to increasing setup and tool cost.
Hollow head parts can be made in multi-blow header cycles. Helical oil grooves can be rolled on shanks. Protrusions having special contours can be formed at the ends or along the shank of tailor-made parts. Lettering and embossing in the form of trademarks, specifications or dates are typical examples.	The number of small protrusions should be kept as low as possible. Hollow upsets increase die wear; thin edges are apt to be the cause of cracked parts. Minimize lettering and embossing to cut cost of dies and preserve the natural flow of metal.
A commercial tolerance of ± 0.003 in. can be held without too much difficulty. Shank diameters kept to -0.001 in. are obtainable, but distortion resulting from subsequent heat treatment sometimes necessitates grinding.	Commercial tolerances should be specified whenever possible, since die costs are less, production rates are increased, and second operations are eliminated. Specify material that does not require heat treatment and make part as short as possible.

What Increases the Cost of Screw Machine Parts?

Monroe Calculating Machine Company
Thomas A. Edison Incorporated

AUTOMATIC SCREW MACHINES long have been used to produce parts: (1) at high rates of production; (2) with uniform overall shape and smoothness; (3) usually to tolerance limits of ±0.002 in. or less; (4) sometimes to tolerance limits of ±0.0005 in.; and (5) in many intricate shapes. The automaticity of the process is another advantage with many machines.

Besides conventional turning, drilling and tapping, machines can be tooled for unusual operations such as eccentric drilling and turning, multiple and cross drilling, end milling, slitting and slab milling, outside and inside burnishing, thread rolling (limited), knurling and marking, and taper turning and facing. While the initial cost of tooling for such operations may be high, this cost can be reduced on a per-piece basis by spreading it over a sufficiently large number of pieces. However, it is one factor affecting the cost of a part, some others of which are as follows:

FACTORS AFFECTING COST	WHY	WHAT TO DO
1. SMALL QUANTITIES	Machine set-up, tools and other overhead must be apportioned over a shorter run.	If parts are standard, order in as large a quantity as possible. Often inventory increase is not as great as the extra cost of a smaller quantity.
2. MATERIAL MACHINABILITY	Poor machinability shortens tool life and causes frequent down time. Free machining material reduces the time required per piece.	Select the most easily machined material consistent with the requirements needed in the part. Perhaps it can be made of free-machining steels or non-ferrous metals.
3. CLOSE TOLERANCES	Requires extra supervision, more expensive tooling, and frequent tool and machine adjustments.	Specify no closer tolerances than are absolutely necessary.
4. SPECIAL THREADS	High cost of special threading tools, thread gages and special inspection.	Standard coarse and fine threads are satisfactory except in the most unusual cases. Specify them if possible.
5. SPECIAL DIAMETER HOLES	Higher cost of special drills, reamers and plug gages.	Use hole diameters obtainable with standard tools. Check whether it would be cheaper to make the male parts or the female parts of standard size.
6. FINISH	Secondary operations are expensive and account for 20 to 100 percent of the cost of parts originating on automatic screw machines.	If the part is not seen or does not move, and requires no close fit, finish is inconsequential.
7. SECOND OPERATIONS	Finishing may involve unnecessary shaving, grinding, tapping, burnishing, or other special treatment.	Check design and use of part. Is special burring, or concentricity necessary? Can one or more operations be omitted?

Data supplied by National Screw Machine Products Association and Cone Automatic Machine Company, Incorporated.

DOLLAR SAVING TIPSHEET ✓ TYPES OF CONSTRUCTIONS

Gray Iron, Steel and Bronze Castings

1. Economic and Design Factors

Considerations when selecting castings molded in sand:

(a) Cost and time required to get into production are low.

(b) Pattern costs are usually low. Pattern cost per casting is a small item when large quantities of the same part are required. When only a few parts are required, pattern costs may be lower than cost of tooling for forming part by other methods.

(c) For assembly with other parts, castings are finished to required dimensions by machining with standard machine shop tools and accessories, therefore, expenditures for new tooling are seldom necessary.

(d) Percentage of material lost in metal scrap depends upon weight of casting and amount of machining needed.

(e) Wide choice of castable metals and alloys permit a selection to satisfy most physical, chemical and metallurgical requirements. Take advantage of casting price, if possible, by selecting a material that the foundry is prepared to produce readily.

(f) High physical properties can be obtained by heat-treating the castings.

(g) Ability to cast parts of irregular contour and shape, and having sections of variable thickness, enables designers to distribute metal economically for maximum benefit.

(h) Low cost incurred when modifying and changing the design of castings to facilitate reduction of costs for handling, machining and assembly operations.

(i) Simplification of production operations and design can often be achieved by combining a number of design elements into a single casting. Parts of any size can be cast to shape in sand molds.

(j) Unmachinable metals can be cast to shape, but most castable metals and alloys can be readily machined.

(k) Machining costs can be saved and design freedom increased by coring out holes, interior passages, and pockets.

(l) Plates and other rolled sections can be joined to castings by welding; and castings can be incorporated into welded assemblies by welding; thus increasing opportunities to reduce manufacturing costs through flexibility and freedom of design.

2. For Quality Castings Check these points:

(a) Heavy sections should not be joined to light sections. If possible, keep all joined parts to the same thickness even when the metal added is not needed to withstand imposed loads.

(b) Avoid abrupt changes in the thicknesses of cast walls, webs, ribs and flanges. If a change of thickness is demanded by design considerations, make the transition from one thickness to another with a gradual taper.

(c) Stagger crossing members such as ribs and walls so that the plane of one member is not continuous. Reduce the number of ribs and walls that connect in one place to a minimum.

(d) Fillet all sharp angles and corners. Use generous fillets; they reduce stress concentrations; and prevent cracks, tears and draws at reentrant angles.

(e) Don't core small holes that must align accurately with other parts, especially if they can be drilled readily.

(f) Draft is required on all parts of the pattern that must be withdrawn from the mold. Average draft ranges from $^1/_{16}$ to $^1/_8$ in. per ft.

(g) Specify metal wanted so that pattern maker can allow for proper contraction. The amount of contraction during cooling in the solid state is different for different metals and alloys.

(h) Be liberal with dimensional tolerances. In general, allow at least $\pm^1/_{32}$ in. for thin sections and $\pm^1/_{16}$ in. for heavy sections. Where closer tolerances are required, call for machining.

(i) Provide ample metal for machining areas that must be finished to close dimensions for fitting, assembly or alignment with other parts, or that for appearance must be finished to remove surface imperfections.

(j) Use cored openings to minimize the area of flat surfaces. Such openings can be closed when necessary by welding in or bolting on covers. Required strength and stiffness of the casting can usually be obtained by providing flanges around such openings.

(k) Design and foundry factors that affect the cost of finishing castings are choice of parting lines, risers or feeding heads, and the requirements for good appearance.

(l) Chaplets and chills are sources of potential trouble to the foundryman. To avoid such trouble, wherever possible design the part so that cores can be supported adequately at strategic places.

(m) Allow liberal openings into the interior of inclosed castings. Such openings facilitate cleaning the casting by permitting easy removal of core sand.

3. Consultation With Foundry

Many basic considerations are associated with foundry practice and the inherent behavior of molten metals. Engineers often can simplify the work in the foundry by discussing a few of these considerations with the foundryman when designing castings and writing essential specifications.

Consultation is desirable especially since most foundries are equipped to produce only a few types such as thin or heavy sections, and cored or plain designs.

Cold Roll Formed Sections

SECTIONS made by cold roll forming are often compared with parts produced by two other methods of production: press brake forming and extrusion. It is the function of the designer to make this comparison both on the basis of cost and of the suitability of part insofar as his product is concerned. Careful consideration of part shape, part material, part function, anticipated rate of production, and the thickness of the section will go a long way toward providing a solution.

Part Material – Material has an effect on the cost of cold roll formed sections in another way besides raw material cost. That way is on ease of forming. As the alloy content of the material is increased – if it be steel – it usually becomes harder and stronger, thus requiring slightly lower forming speeds and perhaps, although not necessarily, more forming rolls and a heavier machine.

▶Cold rolled steel is the material normally roll formed, but aluminum, stainless steel, Monel, brass and copper also are commonly formed. Magnesium is difficult to handle, and special set-ups are required.

▶The form of the material affects part cost. A slitting machine used in conjunction with a battery of roll forming machines may more than pay for itself. Frequently slitting rolls can be incorporated on the first roll of a roll forming machine that is tooled for simultaneous production of several sections.

▶Using cold rolled steel as the base metal, and forming around it a thin section of stainless steel or Monel is much less costly than forming the entire section of the higher priced material.

▶Forming of pre-plated and polished stock or of painted stock is practical and often less expensive than painting individual parts after they have been cut off by a form of flying shear at the end of the forming machine.

▶Insertion of felt, wire, or other materials within a section during the roll forming operation is usually much easier than assembling such sections after forming. In many cases, it represents the only practical method of production.

Part Shape – Molding trim; square, round or fluted tubes; and channel sections, Z's, and other structural sections, are examples of parts that are commonly roll formed. Tubing can be locked together or joined by the addition of a welding pass to the machine. Parts can be curved, coiled, fluted, embossed, and cut to length in the machine.

▶A part with sharp corners requires more roll passes, greater maintenance on the rolls, and is more susceptible to cracking than if designed with adequate fillets. In roll forming, therefore, the radii not only affects part quality but part cost.

▶The easiest shaped part to form is an open symmetrical contour. Relative ease of forming structural shapes is indicated in Fig. 2, No. 1 representing a section that is easy to form, and No. 7 a part that is difficult.

▶Frequently, two parts can be formed as one and cut by a slitting roll at the exit end of the machine. This has the effect of doubling the production rate.

Production Rate–Cold roll forming machines are costly and tooling is an expensive item. Production rates must be sufficiently high to enable the shop to write off such expenditures. However, because a roll forming machine is capable of producing ten million feet of section per year does not mean that it cannot be profitably operated on a small fraction of this production. Just where the line must be drawn cannot be decided by any fixed formula. If quantities are small, however, it may be found economical to buy the shape from a custom roll forming shop.

Thickness of Section – As material thickness increases, so must the size of the machine. Spindle size must be greater to take the heavier loads. Tube mills are available for material up to $\frac{3}{4}$ in. thick, although $\frac{1}{2}$ in. is the maximum common size. Average section thicknesses range from about $\frac{1}{32}$ to $\frac{1}{16}$ in. The thinner becomes the material, the easier the section becomes to form – unless it approaches the thickness of foil.

Part Function – In general, rolled sections, being hollow, have a higher strength to weight ratio than solid members. For molding trim as other decorative parts such characteristics are unimportant, but for structural members, should be investigated. Even though the strength to weight ratio is less with a roll formed section, the total strength and stiffness of a solid section may be far greater.

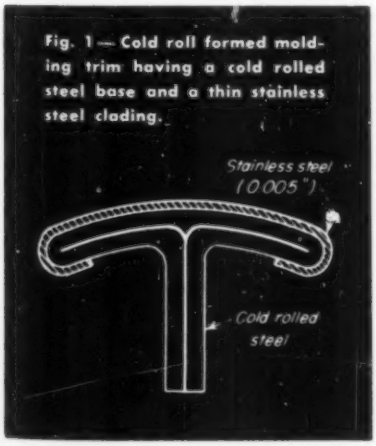
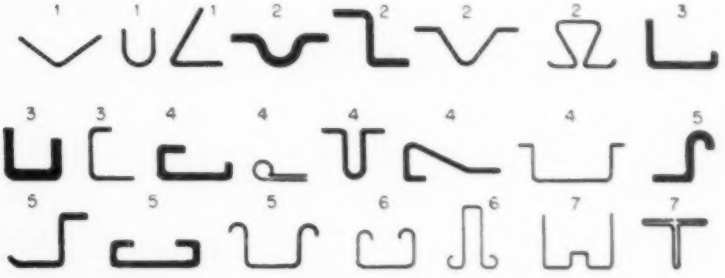


Fig. 1 — Cold roll formed molding trim having a cold rolled steel base and a thin stainless steel cladding.

Fig. 2 — Relative ease of forming channel sections: (1) easiest; (7) most difficult. These classifications should not be considered rigid, but used as a general guide only.



Economics of Forging

HOT FORGING with closed impression dies offers many advantages to the designer and to the manufacturer. The higher strength and improved quality of forgings makes possible more durable designs and with less material. The dense fiber-like structure of the forged metal has greater strength. With proper orientation of the grain flow, the impact strength is also improved. The reduction of machining by forging is important when machine parts are complicated in shape or when the material being used has poor machining qualities.

Forging should be considered when either a large number of parts are to be made or when the shape is complex and would require appreciable machining. It should be used when greater physical strength is desired. Since the expense of forging dies must be absorbed by the parts manufactured, economical fabrication is dependent upon the size, quantity and complexity of the part. For example, forging may be practical for some relatively simple parts only when quantities exceed a thousand pieces or more. There are cases where less than a hundred large, complex pieces were made cheaper by forging. Softer metals simplify the die problem but greater ease of machining raises the quantity of forged pieces that are required for the lowest unit cost.

There are several ways to reduce or offset the initial cost of the die. One method is to forge several pieces at one time. This is particularly useful when a composite forging can be made up of two or more pieces. By simply cutting this forging, two individual parts are made as shown in Fig. 1. Another method is to make

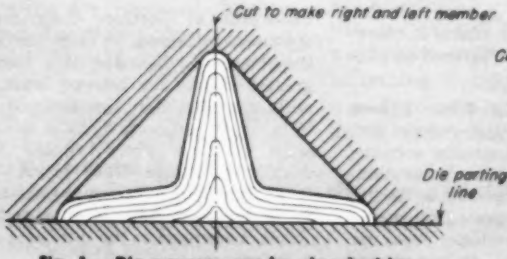


Fig. 1 — Die expense can be absorbed by forging two pieces as one and separating them by a cutting operation.

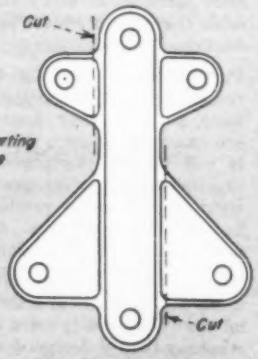


Fig. 2. — By a simple cutting operation, composite or neutral forgings can be made to serve as either a right or left hand member.

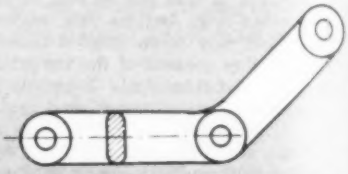


Fig. 3 — Designing with straight lines and circular arcs simplify and reduce cost of forging dies and this is one of the biggest factors that affect the unit cost of forgings.

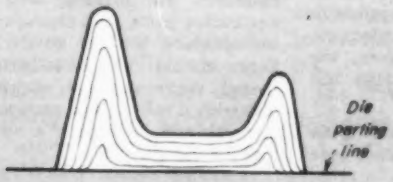


Fig. 4 — Flat surface as parting line reduces cost of die; only upper die requires machining.

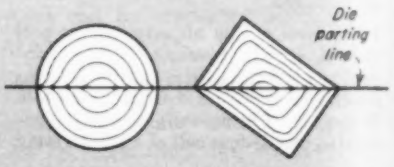


Fig. 5 — Parting line position can be altered to eliminate the draft on straight sided pieces. Forging design should have ample cross-section area to insure adequate flow of metal to the extremities.

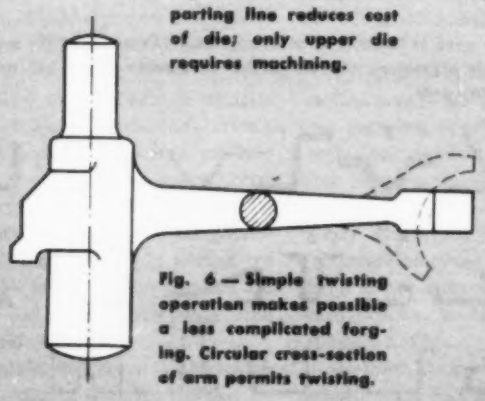


Fig. 6 — Simple twisting operation makes possible a less complicated forging. Circular cross-section of arm permits twisting.

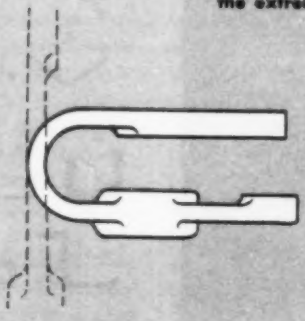


Fig. 7 — Bending of flat forgings simplify manufacture of complicated shapes. Undercuts in forgings can be avoided by welding together forged parts.

one neutral forging which serves for both right and left hand members. By cutting off the unnecessary sections makes the part applicable for either position. This is shown in Fig. 2. When such right or left hand parts have a flat back surface, one forging can be made with the two pieces back to back, as shown in Fig. 1. This method is preferable if equal quantities of each hand are to be made. Combining parts in the forging often produce better flow lines than if the parts were made separately. In addition certain webs can be made much thinner because of the cutting and separating operation.

Since the cost of the forging dies is one of the largest items, certain factors should be kept in mind when designing a machine part. In general, these factors are: large fillets, ample draft angles, and sufficient space for metal flow. Whenever possible, the part should be designed so that the parting line of the die can be straight. With these ideas in mind, not only will the cost of the die be reduced, but its life will be prolonged.

The greatest benefit of this process, besides improved physical strength, lies in the reduction and elimination of machining. In some cases, the part is roughly forged and little machining is required to complete the piece. Forged dimensions can readily be held for broaching or reaming. From a dollar standpoint, closer dimensional tolerances mean higher costs; all surfaces which do not require accurate tolerances should remain in the as-forged condition. Some sources say that a 5 lb part, 10 in. long, can be commercially forged within +0.03 and −0.010 in overall height, and ±0.035 in length. Closer tolerances than these are possible but because of added costs, should be used only when necessary. On flat surfaces, very close limits can be maintained by means of a cold sizing or coining operation. In this way, dimensions have been held within ±0.002 in. on relatively small pieces.

Straight-sided parts having no draft are possible by means of forging. However, such forged parts present other problems and also may result in excessive die wear. This method should be used only when necessary. Dimensions of such surfaces have been held within ±0.005 in. Although close tolerances have been maintained on small forgings, the specific dimensional tolerances that are possible are in proportion to the size and complexity of the machine part.

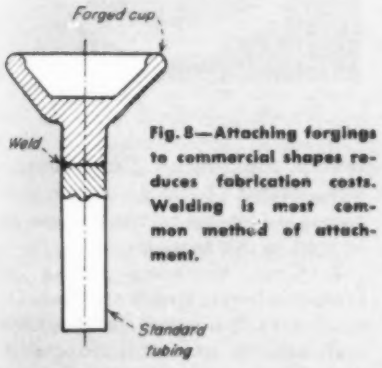


Fig. 8—Attaching forgings to commercial shapes reduces fabrication costs. Welding is most common method of attachment.

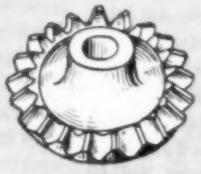


Fig. 9—Gear can be forged to eliminate tooth cutting operation. High production required to justify the more expensive die.

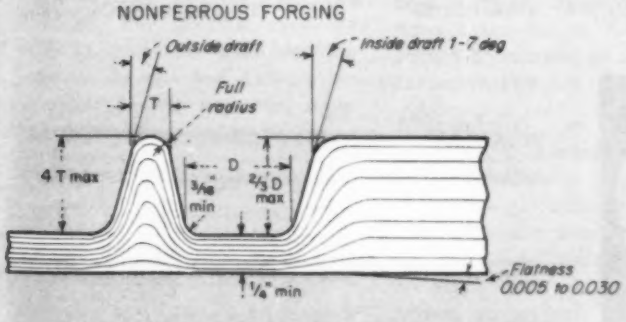


Fig. 11—Forging proprotions of non-ferrous parts should have larger fillet and corner radii. A 6 in. dimension can be held commercially to within ±0.020 inches.

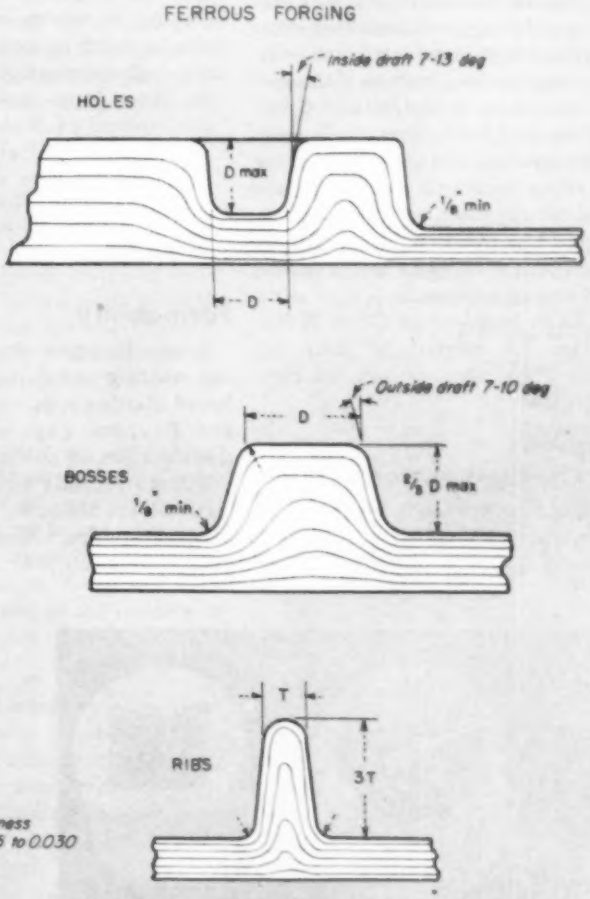


Fig. 10—General proportions of ferrous forgings. Abrupt changes in cross section should be avoided.

Compression Formed Tubing

Factors Affecting Cost

1. "Delivered" tolerances—Total of 0.012 in. on the OD and ±5 percent on average wall thickness for general machining and structural use, and a total of 0.005 in. on the ID of precision-bore tubing—mean low stock removal and more than 50 percent reduction in machining time required to reduce a part to final dimensions. Light machining operations are therefore sufficient, resulting in increased tool life. In many applications, preliminary boring and turning operations are unnecessary.

2. Smooth inner and outer surfaces obtained during production may simplify final finishing operations in precision applications such as hydraulic and pneumatic cylinders and obviates the need for finishes of any kind in less precise applications.

3. When ductility is required in finished tubular parts, economical, low-temperature (600 to 900 F) annealing is sufficient to relieve stresses developed during processing.

4. Extra long lengths (20 to 30 ft.) increase the number of parts cut from a single piece, thereby reducing scrap loss.

Strength and Weight Factors

1. Sizes range from ⅞ to 5¾ in. OD with standard wall thicknesses. Tubes of 6 in. OD can be produced, but wall thickness is limited.

2. Physicals are high for relatively thin wall thicknesses. Yield strength of SAE X1020 tubing is more than 100,000 psi. The resulting high strength-to-weight ratio permits substitution of this precision tubing for thicker-walled stock having equal strength. Hardnesses average 33-RC for 52100 bearing steel, range from 98- to 120-RC for milder grades and from 40- to 41-RC for stainless.

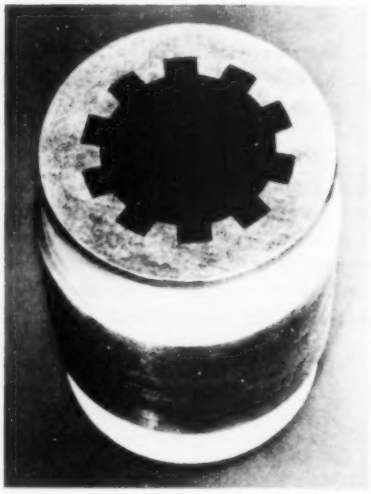
3. High degrees of concentricity and circularity result from the close tolerances held on this type of tubing. Some rotating parts are therefore inherently in balance and balancing procedures can be simplified for sensitive high-speed parts.

4. There is no surface-hardened "skin" around a soft core. Strength is distributed essentially uniformly throughout the tube section, and is not detrimentally affected by the loss of material removed during machining operations.

Formability

1. Standard procedures for bending, welding and flaring can be followed. Heating coils, condenser tubes and Bourdon gage elements are therefore among the applications.

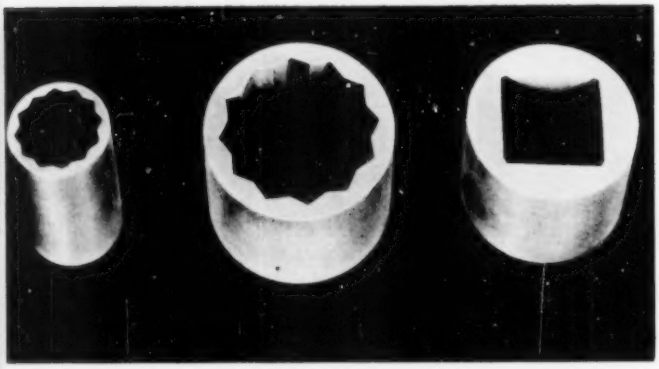
2. Both ferrous and nonferrous materials are die-rolled into this type precision tubing. Steel from mild grades to stainless, aluminum-bronze, cupro-nickel, Dural, Admiralty, Monel, Inconel, copper and nickel are typical metals that can be formed in this manner.

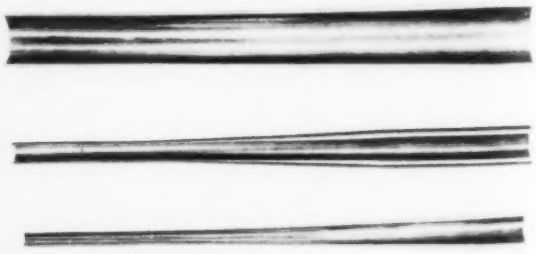


3. Close tolerances permit increases in boring speeds and feeds for synchronization with high-speed operations such as overall sizing cuts, threading, grooving or forming of shoulders and flanges.

4. Inside surface of tubing can be formed as a hexagon, square, triangle, spline or to other special contours including tapers.

Illustrations courtesy Tube Reducing Corporation.





Dollarwise Suggestions for Stampings

Compare the cost of stampings with spun, forged, welded, or machined constructions – keeping in mind the number of parts to be made, the ultimate use of the part, and possible materials to be used.

When designing stamped parts these factors must be considered:

Dies

(1) Use temporary dies (push through type) for small lot production.

(2) Standard dies should be used for large quantities.

(3) Cemented carbide dies combine accuracy with long life. They should be used if production quantities warrant the extra cost.

Investigate the use of progressive dies – especially where products are small and must be held to extremely close tolerances.

Tolerances

Close tolerances can be held for stampings, but – it's expensive. Make all tolerances as liberal as the part will stand. Dimensions on stampings often need not be held to closer tolerances than corresponding dimensions would be on castings. Yet designers constantly specify tolerances as rigid as those used for machining operations. For greatest economy, ±0.002 in. is the recommended tolerance on the size and distance between holes. When necessary tolerances of ±0.001 in. can be held.

On blank dimensions up to 3 in. a tolerance of ±0.005 in. is a reasonable minimum, with an additional 0.005 in. for each additional 3 in. of length.

Hole Piercing

The size and location of holes is usually more important than the contour of the blank. Holes are usually pierced for economy, rather than drilled. Pierced holes must be located at least one metal thickness away from an edge to avoid bulging. If holes are to be used as a bearing surface they must be pierced undersize to allow for reaming. Allow plenty of stock for reaming in order to clear up minute tears and cracks caused by piercing.

Drawing

Make draws as shallow as possible. Successive draws not only mean more stamping operations, but bring in expensive and time-consuming annealing operations. Pick the right deep-drawing sheet for the operation, and watch the sharp corners on drawn parts.

Assemblies

Investigate costs factors involved in brazing or welding stamped sections – particularly to avoid deep drawing. Incorporate matching holes and dowels in mating parts to facilitate positioning for the brazing, welding or bolting of assemblies after they have been formed.

Flanges

To facilitate trimming add at least two metal thicknesses for a flange. A flange should not taper to the metal face. Remember to use a notch or hole in highly stressed parts to relieve partial flanges. A hemmed edge should be notched at the corners to eliminate wrinkles.

Materials

Watch the hardness of the sheet materials used. To eliminate springback by a rehitting process is often more expensive than the initial forming operation. Choose materials that are soft enough to take sufficient set without springback.

Investigate the use of prepolished and plastic-coated materials. Tough plastic coatings now on the market can be sprayed on, will stand distortion of the forming operation, and can be stripped off when desired. Preplated or prepolished sheets will save an expensive operation after the part is formed.

Radii

Make radii as large as possible – a one metal thickness is a minimum radius. For drawing, the radius at the bottom of the stamping should be at least four times the metal thickness – otherwise fractures can be expected.

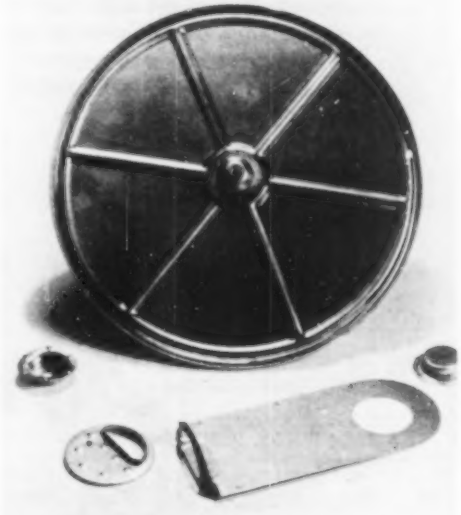
Nested Parts

Design toward shapes that can be easily nested. Avoid special shapes, long tabs and projections that make nesting difficult. Scrap losses soar when large numbers of stamped parts can't be nested.

The time the design engineer spends in cutting, shuffling, and trying a new design will pay off when large quantities of stamped parts, by proper nesting practice, produce low scrap loss percentages.

Designed especially for resistance welding, this simple stamping readily lends itself to high production assembly.

Resistance Welder Mfg. Assn.



Look to Quicker Methods of Fastening and Joining

Within the past few years, rapid strides have been made in speeding up the joining of parts in a sub-assembly, and of fastening such sub-assemblies to the main frame or base. Resistance welding and brazing, quick-acting snap and screw fasteners, fasteners designed to do more than one job, fasteners built into the product, retaining rings, and studs and nuts formed with projections so that they can be projection welded to a base, are perhaps representative of these new techniques in fastening together parts of an assembly.

Many advantages, other than speed of assembly can often be gained by the application of such devices. Ease and speed of disassembly is one; some of the fasteners, true, are damaged and must be replaced if they are removed, but others are designed so that they can be reused. Another advantage is that the fasteners usually can be applied in straight-line production, and do not require that the assembly be routed to a separate department for welding, riveting, or other operations. As a direct result of this latter advantage, the components for the product can be finished (painted, plated, or polished) before the assembly operations.

Quick Acting Snap Fasteners

Snap fasteners take many forms: simple fasteners to hold a material or part in position, a clip or clamp that can be used to hold wiring or piping, or a snap button to fill a hole or give visual access to an indicator.

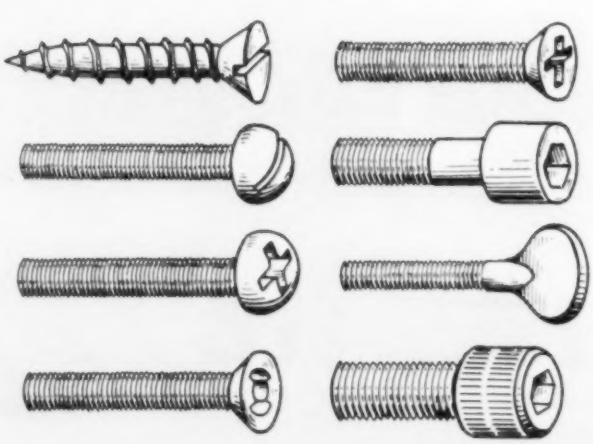
▶Push-on fasteners are devices that can be pushed over unthreaded studs, nails, rivets, or projections. They are available for square, round, rectangular or special-shaped studs. Applications include stampings, die castings, and molded plastic parts of a variety of shapes and for a variety of uses. Fasteners of these types are made removable by using *D*-shaped studs that can be turned to allow them to slip out.

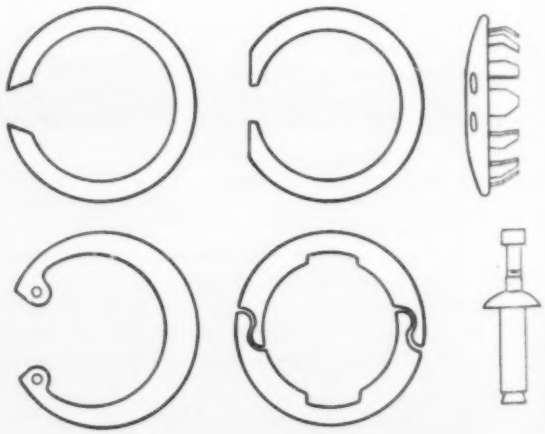
▶When there is access to only one side of the assembly, a tubular clip can be used. When a round or flat-headed rivet or stud is then pushed into this housing, the clip expands and is tightened. Spring tension keeps such fasteners tight, regardless of vibration; they can be installed by hand; and they are available in either permanent locking or removable types.

▶Plug buttons are just what their name implies: they are used to plug a punched or drilled hole. Made in an almost unlimited variety of sizes and shapes, they can be solid, covered with a wire mesh, be fitted with a glass cover for use with indicator lights, have a center hole for wiring, or have an opening for a snap-in electric switch. The finish often is made to match the product in which the button it to be used, although a chromium, brass or nickel finish is more common. The economy in such fasteners is apparent – they can be used to replace more costly machined or threaded parts.

▶Snap fasteners are not necessarily confined to holding a panel or flat section of material. Moulding fasteners for holding chromium or stainless steel trim on vehicles, household appliances or other products illustrate this point. This type is usually snapped into the moulding or slid in from the end and then snapped into a hole. Thus, the molding can be assembled if one side of the panel is "blind," and no turning or staking is required.

▶Wiring harness bands and tubing and wire fasteners are two of the major items in a more specialized class of fasteners. Instead of being fastened to a panel or stamping by bolted assemblies, the fastener is snapped into a punched hole and the tubing and/or wire clamped into position.





Screw Fasteners

Quick acting screw type fasteners are constructed so that they can be quickly mounted on the assembly, have fast threading action, or both.

▸One widely used type snaps into position, and provides a bearing surface for the thread of a screw or threaded bolt. Two distinct locking forces are exerted by this fastener — one that forces the prongs against the root of the screw thread, and another created by compression in the prongs and base, that locks and holds the bolt in position. The prongs compensate for quite a large variation in thread tolerances, so that the fastener locks securely on oversize or undersize threads.

▸One of the greatest sources of economy in the use of spring type fasteners is that the nut element, namely the prongs, can be stamped directly into the part that is to be assembled or attached. Thus, by using stamped hinges for the door of an oven or other appliance, the prongs for the fastener can be stamped directly into the hinge and the support nut unit is not required.

▸Blind rivets with threads are still another type of fastening device that may save time and money in assembly. When upset with a heading tool, the rivet is firmly seated against the material being fastened, and the other section then can be fastened against the panel with a threaded stud. Countersunk, brazier, or flat head types are made in aluminum, brass, or steel.

▸Precision screw fasteners with American Standard Screw threads also are made in an infinite variety of sizes and shapes, each having advantages that make them the most economical for many applications. With this type, the strength of the fastener is more important than ease of assembly. As a result of that strength, frequently one of these types will hold an assembly where several of the previously described types might be necessary. The cost of the fastener is insignificant compared to the preparation of the hole and assembly of the parts.

Hollow head screws provide additional surface for the driving tool and thus decrease slippage and driving time. Many manufacturers discovered that when they switched from solid head screws to hollow head screws their refinishing costs dropped to such an extent that it represented many times the cost of the higher priced screws. Whenever the slip of the screw driver in the slotted head marred the finish on the parts being assembled, it was necessary to entirely disassemble the pieces and send it back to the finishing department for retouching and refinishing.

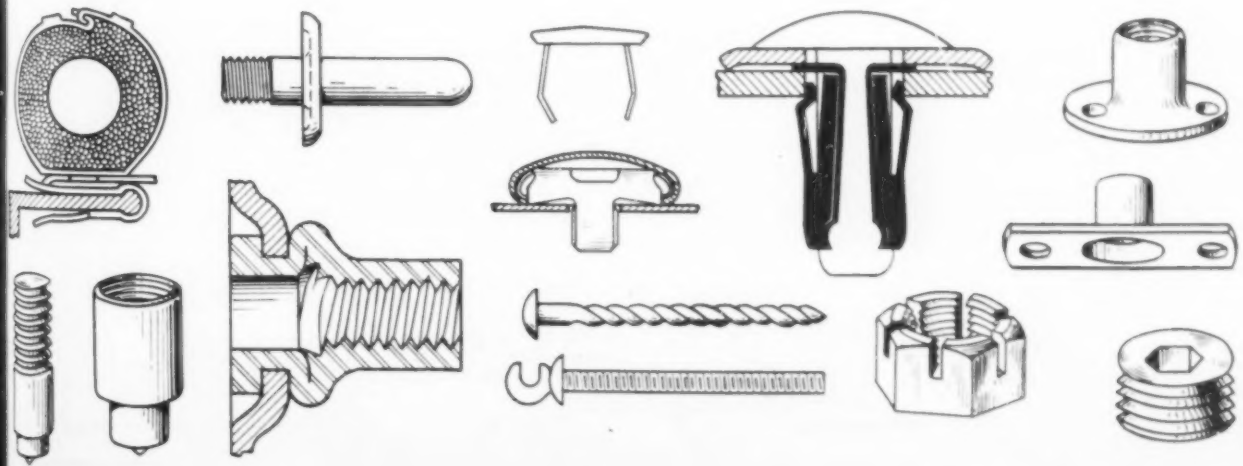
Savings in retouching and refinishing costs are not the only economies in the use of hollow head screws as compared to solid head screws. The former type can be driven much quicker and more conveniently, particularly in hard to get at places. Most types of hollow head screws are so designed that the screw can be gripped by the end of the driver, making it unnecessary for the workmen to hold the screw while it is being started.

▸Lock nuts of various designs, or studs so designed that the thread locks and seals itself as it is turned into a standard tapped hole eliminate the need for lockwashers or other holding devices. Machine screws also are available with lockwashers as an integral part. Whenever assurance of positive locking is essential, the old cotter pin with castellated nut, or a wire nut is used.

▸Cold headed fasteners of special shapes frequently are less costly than standard fasteners since they can be designed to perform more than one job. There are some limitations as to what can be accomplished, and production rates must be sufficiently high to justify die costs, but the cold heading process by which such parts, as well as many standard fasteners, are made offers definite possibilities for lower fastening costs.

▸Self-tapping screw for fastening plastic parts, wood, soft metal, and other components makes unnecessary the threading of holes. The screw makes its own thread, but there are many types and kinds of such devices, and each must be selected on the basis of the job it has to do. Like all of the fasteners herein discussed or mentioned, determining the class to use for any specific application is not enough: the type must also be selected.

▸In designing a fastening for cover plates and similar constructions which are to be held by screws it is often economical to use ring assemblies in which the nuts of whatever type are to be used are positioned in the ring. This type of construction greatly simplifies the assembly operation as it requires the handling of only one assembly.



▶Lines of special fasteners have been developed for assembling tubes and circular ducts made of sheet metal. These fasteners are in the form of a band which wraps around the flanged ends of the ducts. Special types of clamps or thread connecting ends are developed to pull the ends of the band together and put the band in tension. Where quick disassembly is desired, a cam or toggle type clamp is used.

Welded Fasteners

▶Since welded fasteners usually are used with the projection welding process, and so are formed with projections on the surface that is to be joined, they can be fastened quickly to a metal surface and become an integral part of that surface. Welding a threaded nut to a sheet metal section in which a hole has been punched is much faster and simpler than providing additional metal around the hole to obtain an adequate bearing surface, and then drilling and tapping the hole to the required specifications.

▶Projections on nuts are formed on the bottom, sides, or top, or the nut is formed in a right angle with the projections on the base. These projections provide a path for the welding current. When formed with a projection around the thread, the nut becomes self-locating in the hole.

▶An adaptation of projection welding is the stud welding process, wherein studs are welded directly to plate or formed parts, usually of ferrous material, thus making unnecessary a drilling and tapping operation. Design simplification, improved appearance, and ease of production when one side of the part is "blind" are other advantages besides production economy.

▶Another form of projection welded fastener is the nut cage, the principle of which is similar to that of the other welded fasteners. Even on such a simple item as this, over 57 known types are known to exist. (See PRODUCT ENGINEERING, April, 1950). It is obvious that the cost of such a cage and nut is more than that of a nut with formed projections, but alignment is not so critical, since some looseness exists in the assembly.

▶Special fasteners of all types can be formed with projections. The advantage of using a welded fastener as compared with welding the assembly is, of course, that the product can be disassembled easily.

Retaining Ring

Retaining rings, whether of the wire or stamped type, also are a form of fastener – a snap fastener. When snapped in a groove in a bored hole or on a shaft, they form a shoulder that locates and holds a part or assembly such as gears, bearings, or bushings.

▶If used to replace a cotter pin, better holding power is obtained, the assembly time and machining time being about equal in either case.

▶If used to replace a machined or pressed shoulder, the saving is in machining and assembly time, the cost of the ring being insignificant.

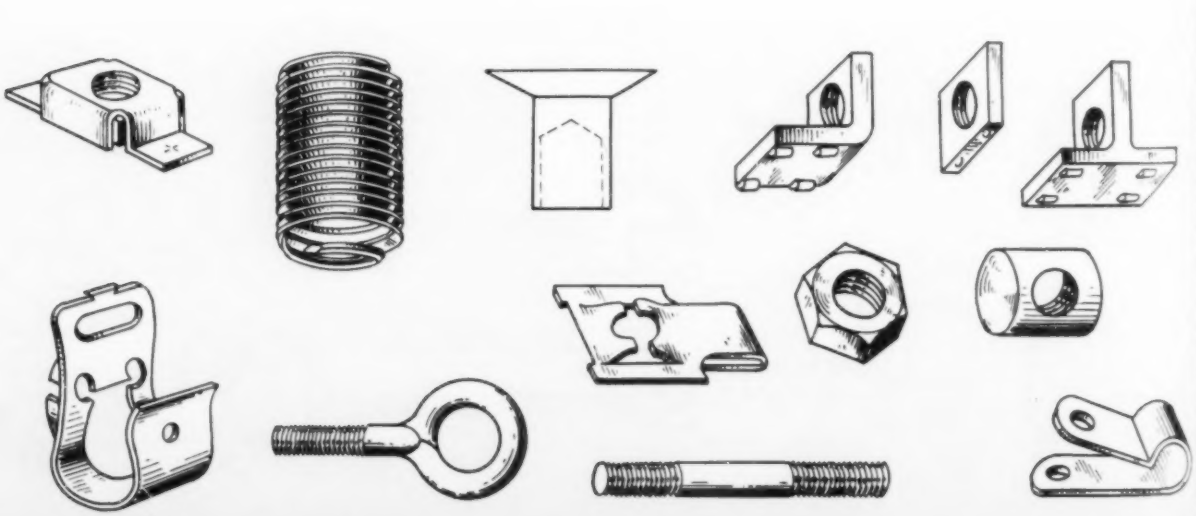
▶If used to replace a threaded assembly, again machining and assembly time are much less.

▶If a bowed ring is used that takes up end thrust, tolerances on the parts for the assembly become somewhat less critical and the entire assembly is easier to put together.

When these types of rings are used for holding together an assembly on a shaft or in a housing it will usually be found that the design is greatly simplified and the number of pieces required greatly reduced. Some self-locking rings with prongs do not require any groove to hold them in position. The ring is simply slipped over the cylindrical member and pushed into place.

The fasteners described on these pages do nothing more than illustrate the basic principles utilized with some of the newer types to achieve faster assembly at lower cost. As previously indicated, the modification of the shape and contour and size of such fasteners number in the thousands.

Many are specialty items designed for one class of product, or even one product. One concern currently is adding to their line at the rate of about 30 to 70 new or specially modified fasteners each week. As a result, it is practically impossible to set up a check list on fastener selection because so many different types are involved. It should be remembered, however, that if the fastener is special, it usually is small and die costs therefore are not exorbitant when relatively large quantities are involved.



Improvements in refrigerator motors over the past 20 years. The decrease in size and increase in rating was made possible largely by better insulation. Note improvements also made in mechanical construction: 1930, riveted; 1940, spun shroud; 1949, argon arc welded.

	1930	1940	1949
Weight of iron, lb	7.20	6.13	3.96
Weight of copper, lb	2.10	2.00	1.81
Weight of insulation, lb	0.70	0.47	0.27
Total weight, lb	10.0	8.60	6.04
Stack height, in.	2.0	1.5	1.0
Rotor weight, lb	5.0	3.8	2.78
Output, watts	180-200	220	240

The success or failure of a product often can be traced directly to the materials of which it is made. But how can the designer go about selecting a material in a logical and intelligent way?

This Problem of Materials Selection

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ALTHOUGH MATERIALS SELECTION is one of the most important functions of the design engineer, there is, unfortunately, no single approach to the problem that will insure optimum or even acceptable results. Sometimes selection must be based on past experience with materials and design forms. But when the designer lacks this experience, or when the product functions are new, selection must be made on the basis of properties measured in the laboratory or evaluated by simulated service tests. In either case, the task becomes a balance between the available knowledge of materials versus the service requirements.

For convenience, the primary factors in the selection process may be grouped under three headings: Suitability, availability, and cost.

Suitability. A suitable material must have the properties to perform its functions in the product. It must lend itself to the proposed method of fabrication. And it must be capable of withstanding for its intended life all the conditions of temperature, corrosion, loading, and aging that it may face during shipment, installation, maintenance, idleness, and usage.

Usually, the metal first is selected on the basis of the properties that it must have to perform its function in the finished product – electrical conductivity or resistivity, thermal conductivity or resistivity, tensile or compressive strength under static or dynamic loads, stiffness, hardness, or others. The properties that the metal must have so that the product performs satisfactorily under the conditions that are encountered in service are of equal importance: Corrosion resistance, strength or hardness at high or low temperatures, or wear resistance under intermittent or continuous service may dictate choice.

For example, the material for the serrated shredder of a kitchen garbage Disposall unit must be extremely hard; it must also be resistant to attack by foodstuffs or dilute chemicals. Starting with low-distortion, air-hardening die steels, over 10,000 microhardness determinations were made on the effect of alloying elements to develop a suitable material. The material finally selected has sufficient strength, impact resistance, machineability and corrosion resistance to fulfill all requirements.

An independent testing laboratory found the Disposall unit only a little slower in action after test with 6,300 lb. of waste consisting of bone and meat, vegetable, fruit (including many pounds of peach pits), cherries, and cherry pits...and many types of melons. To all this was added 1,000 lb. of sand, 550 lb. of glass bottles, pails full of gravel, several bushels of granite, 1,200 lb. of newspapers, bushels of coal, cinders, and ashes, tin cans, hundreds of pounds of limestone, nails, tacks, and screws, and a few ½ in. galvanized malleable iron pipe fittings. This is suitability to product function.

With one or several materials tentatively selected on the basis of phy-

sical and mechanical properties, the designer then can further narrow down the list by choosing the ones most suitable for low cost fabrication. In this respect, the choice may vary from plant to plant, depending on the manufacturing facilities and availability of skilled labor. Finally, the material must be capable of being finished into an attractive product, although if the product is located within a casing or housing, this feature may be of secondary importance. A check list of some of the factors that fall under the classification of suitability are shown in Table I. Which feature is of major importance depends, of course, on the product application, but all may be necessary to the successful development of the product.

Availability. A suitable material is of no use if it is not available for prompt delivery in the right form and condition. Prompt delivery generally implies supply from at least two sources to reduce the hazard of a labor strike in the supplier's plant.

All designers know of the materials substitutions required during the last eight years because preferred materials were not available. Fortunately, few shortages exist in basic materials today. Numerous design changes should be the result of this improved availability.

Costs. Cost considerations naturally follow the criteria that a product must possess the greatest value per dollar expended. The cost of materials, especially mill products, comprises a base price plus extras for non-standard close tolerances, out-of-size dimensions, special quality or treatment, and below-norms in quantity. Such extras are of importance in obtaining low cost designs and should be "designed-around" where possible.

Besides cost for raw material, other costs must be considered. These include the cost of fabrication, scrap losses resulting from fabrication, and assembly costs. Here the designer faces the problem of balancing one design with its material form against another having different form. One example is the comparison of a casting vs. a weldment. Another is the use of die castings vs. brazed and welded punch press assemblies. Per-

Table I—Some Factors Involved in Determining Product Suitability of Metals

1 MECHANICAL AND PHYSICAL PROPERTIES

- Melting point
- Transformation point
- Recrystallization point
- Specific gravity
- Electrical conductivity
- Electrical resistivity
- Thermal conductivity
- Thermal resistivity
- Coefficient of thermal expansion
- Ultmate strength, tension
- Ultimate strength, compression
- Yield strength, tension
- Yield strength, compression
- Proportional limit
- Modulus of elasticity
- Elongation in 2.0 in.
- Cup ductility
- Torsion properties
  Modulus of rigidity, Yield strength, Proportional limit, Strain at rupture.
- Ratio of tensile strength to density
- Ratio of compressive strength to density
- Ratio of torsional strength to density
- Hardness
  At sub-zero temperatures, At room temperatures, At elevated temperatures.
- Damping characteristics
- Impact strength
- Creep rate
  At room temperature, At elevated temperatures.
- Stress rupture time
- Notch sensitivity
- Endurance limit
- Other
  Reflection, corrosion and oxidization resistance, Abrasion resistance, Permeability or dielectric constant, Arc resistance.

2 ADAPTABILITY TO PROPOSED FABRICATION METHODS

- Casting
  Die casting, Investment casting, Plaster mold casting, Sand casting, Permanent mold casting, Centrifugal casting.
- Molding
- Forming
  Bending, Stamping, Spinning, Die forming and drawing, Electroforming, Roll forming, Press brake forming, Pressing, hot or cold, Stretch or compression forming, Fluting, Embossing, Engraving.
- Forging
  Hammer, Upset, Drop die, Header.
- Metallizing
- Powder metallurgy
- Extrusion
  Die, hot or cold, Impact.
- Heat treating
  Hardening, Annealing, Sub-zero treatment.
- Surface hardening
  Cyaniding, Flame hardening, Nitriding, Induction hardening, Carburizing, Malcolmizing.
- Machining
  Turning, Milling, Drilling, Grinding, Reaming, Honing, Tapping, Contour Milling, Planing, Broaching, Chasing.
- Other
  Roll threading, Cold heading, Flame cutting, Friction sawing, Swaging.

3 ADAPTABILITY TO PROPOSED ASSEMBLY METHOD

- Arc Welding
  Manual d-c, Manual a-c, Automatic d-c, Automatic a-c, Submerged arc, Shielded arc.
- Resistance Welding
  Spot, Projection, Butt, Seam, Flash.
- Brazing
  Resistance brazing, Torch brazing, Induction brazing, Furnace brazing.
- Gas Welding
  Manual, Automatic.
- Soldering
- Riveting
- Others
  Self-tapping screws, Retaining rings, Standard bolts, Metal stitching, Threaded joints, Cementing, Shrink and press fits, Staking, Crimping.

4 ADAPTABILITY TO PROPOSED FINISHING METHOD

- Plating
  Cadmium, Zinc, Copper, Chromium, Nickel, Silver, Other.
- Polishing
- Buffing
- Scratch brushing
- Burnishing
- Barrel tumbling
- Sand or grit blasting
- Chemical Coatings
  Phosphates, Oxides.
- Shot peening
- Organic Coatings
  Natural Resins, Synthetic-thermoplastic and thermosetting (incl. Silicones).
- Painting
  Varnishes, Enamels, Lacquers, Wrinkle Finish.
- Staining
- Etching
- Coloring
- Electropolishing

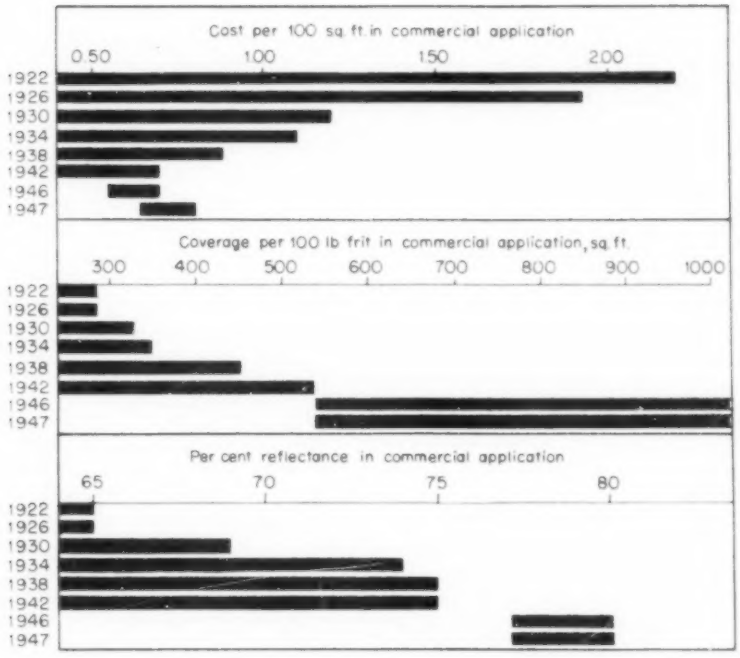


Fig. 1 — How porcelain enameling frit has improved in quality and decreased in cost: 1922, fluorine opacifier; 1926, antimony opacifier; 1930, 1934, and 1938, improved antimony opacifiers; 1942, zirconium opacifier; 1946 and 1947, improved zirconium opacfiers (solid bar) and titanium opacifiers (yellow bar). Better opacity and higher acid resistance are but two of the quality improvements.

haps the greatest single factor in deciding between several suitable materials for a product is the processing they will receive. The processing depends in turn mainly on the quantity to be produced and the size and complexity of the part.

In job shop operations, products are manufactured to order. Such products are generally similar but seldom exactly the same. Accordingly the designer is restricted to the use of flexible production equipment. Generalized machining operations, hammer forgings, sand castings, flame cut sheets, spun sections, rolled shapes, and weldments comprise his forms. Sizes must be limited to the general purpose equipment he has in his shop, those he can obtain in existing vendor shops, and those that can be transported. New specialized capital tooling investments usually cannot be justified for each design, and the labor costs accordingly are high.

High production products, by contrast, justify special tooling for mass producing processes. These include die forging, extruding, casting, and forming processes, plus automatic machining, often with special-purpose machine tools, automatic handling, in-line production and assembly, quality control of components at operator level, and automatic testing. All of these production methods contribute to high value per dollar cost but make the materials selection problem more complex because of the many choices that might be considered and the investment involved.

Between these two extremes lies the product that may occasionally justify specialized tooling but which is committed to that tooling for a long period, often of years, to justify costs. Materials selection in this field is frequently influenced by more-generalized low-production methods because of the freedom of change they provide.

These examples are typical of the considerations affecting material selection. The large number of properties that may be of importance in a particular application requires complete visualization of the product requirements and careful examination of the available materials.

Table II — Comparison of Finish Developments

TYPE OF FINISH	RATINGS, PERCENT						
	Appearance	Moisture Resistance	Grease Resistance	Color & Stain Resistance	Mar & Scratch Resistance	Chip Resistance	Comparative Ratings
Lacquer (1928-1931)	31	40	26	22	46	25	31.7
Alkyd Resin (1932-1942)	81	74	50	45	60	90	66.7
Urea Alkyd (Early, 1945-1948)	71	66	71	81	81	61	71.8
Urea Alkyd (Present, 1948-1949)	80	72	87	82	87	58	77.7
Vinyl	76	65	100	91	61	95	81.3
Silicone	82	82	100	92	82		78.2
New Complete Synthetic Alkyd	80	90	100	95	90	95	91.7

Materials Changes

A material choice, once made, is seldom permanent. A change may come about because of

1. New materials developed by the manufacturer.
2. New materials developed by suppliers.
3. Fluctuations in the materials price market.
4. New use requirements for the product.
5. Operational difficulties.

Perhaps the most frequent cause of a materials change is the ever present effort by a company to develop and improve its product. In the transformer business, for example, there has been an outstanding saving in materials through the improvement of silicon core steels. Silicon is added to these steels because the high electrical resistivity obtained decreases eddy-current losses. Improved magnetic properties are obtained through utilization of anisotropic (directional) grain characteristics. The introduction of core steels possessing a high degree of crystal

orientation in the direction of magnetization has led to a 50 percent saving by weight in steel, copper, insulation, and oil in the 3 KVA transformer in the last ten years.

The electric motor business provides another example. Use of Formex insulated wire in place of treated cotton insulation reduced the insulation thickness necessary to obtain adequate dielectric strength. In turn, the motor size is smaller, the windings cost is less, and less steel is required. The comparison for refrigerator motors in 1930, 1940, and 1949 is shown in the heading illustration. Note the improvement in mechanical construction effected between models.

An example of finish developments is contained in Table II. Part of the change resulted from improvements in surface preparations, both physical and chemical, and the remainder from improved finishes. The last three finishes mentioned are still under development.

Another finishing development that has made outstanding strides is porcelain enameling. The development has been marked by continuously improved opacifiers and continuous decreases in the application weight. Yet the enamels in use have maximum opacity and high-quality acid-resistance with minimum weight. The trend since 1922 is shown in Fig. 1. Further developments now under way are directed at a reduction in firing temperatures. Common practice now is to use temperatures of 1500-1600 F. A later trend is to fire at 1300-1500 F. Besides reducing fuel and furnace costs, lower temperatures also reduce warpage and distortion and make possible broader design possibilities; frequently, too, mild steel can be used as the base material instead of premium enameling iron.

A further example of continuous improvements in materials are the high temperature metals for steam and gas turbines blades, and for the combustion chambers of controlled atmosphere furnaces. The problem has been to develop materials having sufficient creep resistance and an ability to withstand corrosive attack from the atmospheres. Recent work has been directed toward improving high temperature fatigue strength, use of radio-active isotope tracers in constituent studies, vacuum melting techniques, ceramics-metal combinations, and of specially developed high temperature alloys for each application.

New Materials Developed by Suppliers. Developments by suppliers are typified by the recent development of nodular cast iron, which has high strength and ductility; the introduction in the past few years of high strength aluminum alloys; the development of thermistors, which are sensitive negative-temperature characteristic resistors; new silicone oils, greases, resins, and rubbers; extruded and moldable nylon for higher-temperature thermoplastic parts; and the continued progress in powdered metal combinations and surfacings.

In products that utilize fractional horsepower electric motors, nylon is being used for low cost molded gears. Fig. 2 and also for wear-resistant bearings. Powdered iron gears with copper impregnation, Fig. 3, also have been found to be acceptable for light power gearing.

However, suppliers' developments that affect materials selection are not limited to materials as such. Often a process development causes a significant change. Injection molding of plastics, and the more recent low-pressure rubber-bag molding techniques are examples of process improvements that furthered the substitution of plastics for metals. Other examples include rubber bonding, the new fluid pressings, hydraulic forming, and metal stitching.

Price Shifts. Shifts in the price of materials is another reason for mak-

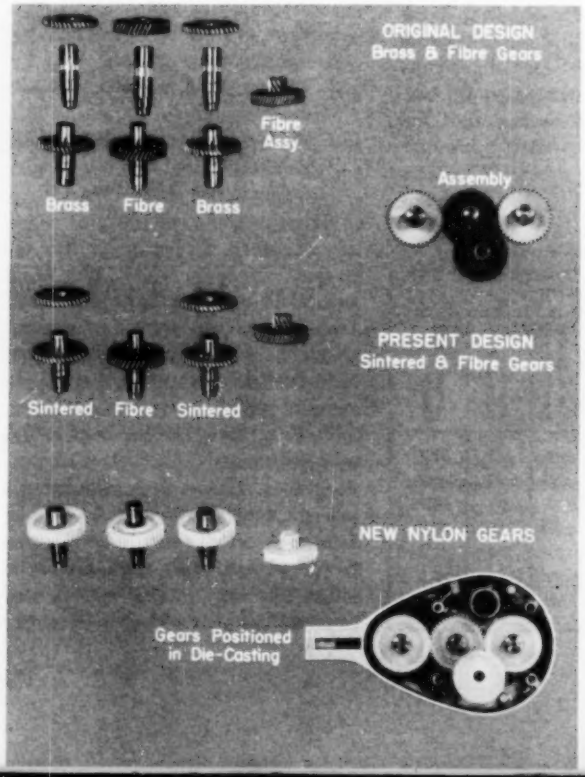


Fig. 2 — One of the newer types of material used for fractional hp gearing is nylon. These gear trains represent the old, present, and new gearing for a food mixer.

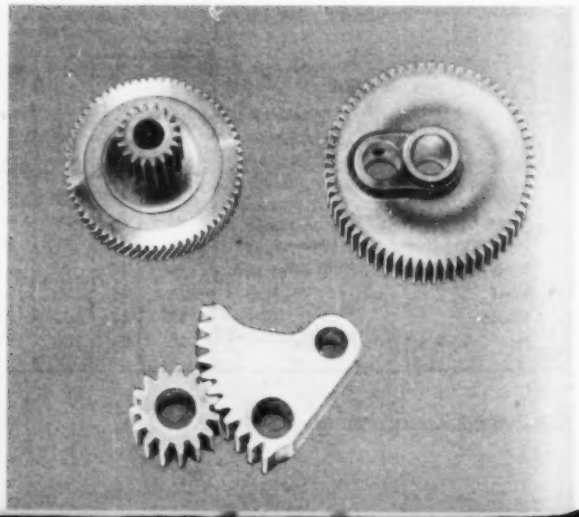


Fig. 3 — Powdered and sintered iron gears with copper impregnation are less costly than cut, ground, or die cast gears, yet can be used as power gearing in small sizes. These gears are for a ½ hp drive for an automatic clothes washing machine.

ng a change. For example, cotton braid and cotton and jute fillers were used extensively before the war for cord sets and wiring materials. Glass fiber was equally suitable but more costly. The increase in labor costs during and since the war has resulted in a large increase in cotton prices, but glass has not increased as much since its price is dependent mainly on processing. Accordingly, glass fiber is replacing cotton as an insulation material for such applications.

Another example is the use of 2S and 3S aluminum in the manufacture of liners, evaporators, and shelves for home freezers and two-temperature refrigerators. Before the war, evaporators were made from stainless steel sections that were resistance welded into an assembly. The lower price of aluminum since the war, the excellent corrosion protection obtained by anodizing, the good thermal conductivity that is an inherent property of aluminum, and the development of furnace brazing techniques for joining aluminum parts have since made aluminum an attractive material. Two methods of assembly are shown in Fig. 4 for a finished liner and a shelf.

The current prices of aluminum alloys may make them as attractive as die cast zinc for parts above approximately 1.0 lb. in weight. The price of magnesium too has been reduced to such an extent that it is often less expensive than aluminum.

Today titanium is in the same position as aluminum was in 1920. It is an abundant metal, has the highest strength to weight ratio of any of the metals, and possesses other attractive properties, as described in the November 1949 issue of PRODUCT ENGINEERING. The future should bring increasing applications for this metal.

New Requirements. New requirements are an understandable reason for making changes in materials. Increased load ratings, longer rated life, and new applications involving different environments all may necessitate materials changes to obtain suitable performance. In the aircraft field, carbon brushes for commutator motors had short life at high altitudes until the importance of oxygen in forming a lubricant was understood and suitable oxides were provided in the brushes. Military equipment for the tropics required special protection in the form of corrosion-resistant packaging, and fungicides for organic materials became important.

Operational Difficulties. Finally, another reason for making changes in materials is unsatisfactory performance in service. An example in the automotive industry was the brineling of automobile bearings during shipment. A similar problem on torpedo gyroscopes occurred during the war and was cured by using throchoidal pivots instead of conical ones to increase the load capacity of the ball contact.

An example that occurred recently was the failure of lightly loaded electrical contacts to make a circuit after a normal period of use. Electron diffraction studies and microchemistry were needed to discover that minute flakes of plastics and fiber, if present, would burn in the arc to form a thin insulating film on the contact.

No Material Is Fixed

It thus is apparent that just as the designer must periodically reevaluate his product to make it more attractive, more serviceable, and less costly to build, so must he constantly reanalyze the materials of which it is made. Many of the product improvements in recent years are directly attributable to improvements in materials. And many of the new products that have come into prominence within the past few years could not have been practical without significant advances in materials.

As a matter of fact, whenever a group of designers and engineers gather together to discuss new developments in the light of past experience, references to materials come up again and again. The advantages of high compression, high speed internal combustion engines were known to engineers years ago, but it has been only recently that the materials became available to make them within reasonable weight limitations. The gas turbine engine, whose efficiency increases phenomenally with each 100 F raise in temperature above 1000 F was first suggested before the turn of the century, but it was not until the thirties that practical machines were developed and not until just prior to war that they were being made in any appreciable numbers. Again materials were, and still are, the problem.

Kettering once said that engineering consists of thinking and materials — the more thinking, the fewer materials. As the previous illustrations demonstrate, it is also true that the better the materials, the less there is of the product and, the less its cost.

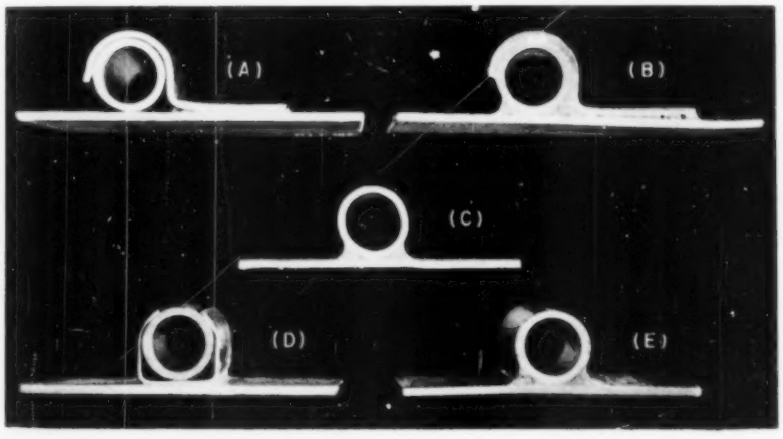


Fig. 4 — Methods of attaching aluminum tubes to aluminum sheets by furnace brazing: (A) clamped tube with clip made from clad brazing strip, joined to sheet on under side with brazing alloy; (B) finish brazed assembly for (A); (C) brazed joint with clip made entirely of brazing strip; (D) clamped tube with "U" clip of clad strip joined to sheet on under side with brazing alloy; (E) finish brazed joint for (D).

Cost Factors in Molded Plastics

THE MOST IMPORTANT FACTORS affecting the cost of molded plastic products include:

1. Material – cost per unit volume (see accompanying chart), properties, material flow, economy of handling.
2. Design of molded part – shape, tolerances and finishes.
3. Method of molding – automatic, semi-automatic or hand molding.
4. Molds – mold design, number of cavities, mold finish and mold maintenance (volume and duration of production).

The materials and design factors are often most important from a cost standpoint. Following is a general description of all the common plastics that are useful in engineering design.

Thermoplastics

Usually injection molded or extruded.

Nylon – very tough, high tensile strength, good elasticity and chemical resistance.

Cellulose acetate – good moldability and complete range of colors and opacity. Good impact and mechanical strength.

Cellulose acetate butyrate – somewhat better weather resistance than acetates. Less subject to warping at moderate temperatures and high humidities.

Acrylics (Methyl methacrylate) – crystal clear or color transparent. Excellent appearance and dimensional stability, good optical qualities, weather and water resistance.

Polystyrene – lightest weight plastic. Has the best water resistance, with excellent electrical properties and resistance to chemicals. It is comparable to fused quartz as an electrical insulator. Moldability is good and physical strength is maintained at low temperatures.

Vinyls – Superior chemical resistance, good dimensional stability, high dielectric strength. Useful where flexibility is an asset. Rigid formulations are characterized by thermal and light stability, as well as toughness.

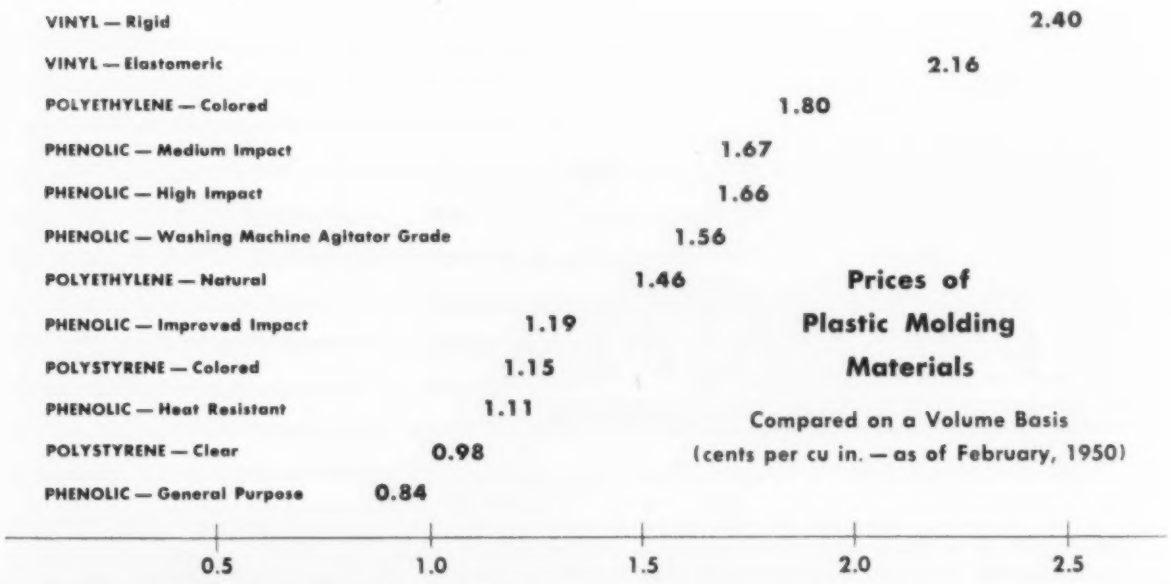
Polyethylene – an opaque semi-rigid plastic which has excellent electrical properties and chemical resistance.

Fluorine plastics – superior resistance to corrosive chemicals and high temperatures. Flexible formulations are excellent in gasketing applications. Excellent electrical properties.

Thermosetting

Usually compression molded (or transfer molded).

Phenolics – these are the "workhorses" of the plastics industry. Excellent strength and rigidity, making them useful for a wide range of structural products. There are 8 general classes of phenolics: General purpose; high dielectric strength; moisture resistant; acid and alkali resistant; impact resistant; wear resistant;


VINYL — Rigid 2.40
VINYL — Elastomeric 2.16
POLYETHYLENE — Colored 1.80
PHENOLIC — Medium Impact 1.67
PHENOLIC — High Impact 1.66
PHENOLIC — Washing Machine Agitator Grade 1.56
POLYETHYLENE — Natural 1.46
PHENOLIC — Improved Impact 1.19
POLYSTYRENE — Colored 1.15
PHENOLIC — Heat Resistant 1.11
POLYSTYRENE — Clear 0.98
PHENOLIC — General Purpose 0.84
Prices of Plastic Molding Materials
Compared on a Volume Basis
(cents per cu in. — as of February, 1950)
0.5
1.0
1.5
2.0
2.5

Courtesy Bakelite Div., Union Carbide and Carbon Corp.

heat resistant; low power factor. Wood-flour filled phenolics are used for general purpose applications. Cotton flock provides improved strength, and macerated rag filler is used for greatest impact resistance. Rag-filled phenolics are more difficult to mold than wood-flour filled, and involve more design limitations.

Ureas – can be molded in translucent or opaque form in a complete color range including pastel shades. Phenolics, on the other hand are stable only in dark colors. Ureas compare favorably with phenolics for electrical properties and have better arc resistance. Thick or non-uniform sections sometimes impose design limitations, since more critical cure conditions are required.

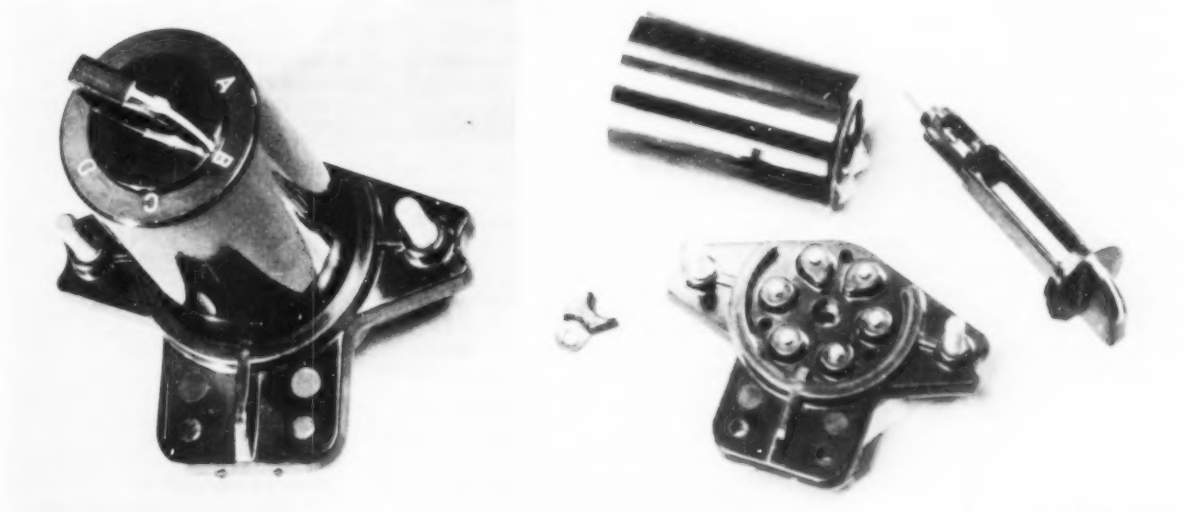
Melamines – similar to the ureas except that moisture absorption is lower; surface hardness and arc resistance are good.

Alkyds – molding compounds are relatively new. Advantages are high speed molding at lower pressures than conventional thermosets. Excellent electrical properties and heat resistance.

Silicones – molding compounds are still somewhat of a specialty and consequently quite costly. However, their use is justified when extreme temperature and electrical conditions are encountered.

Electric Manufacturing Co., Inc.

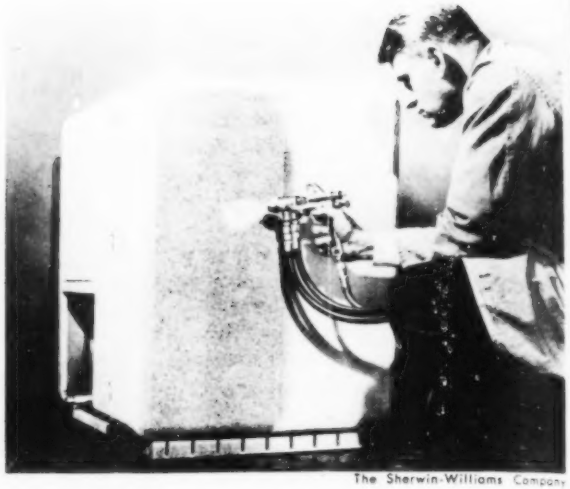
Two-color injection molding is responsible for large savings in such products as calculating machine keys molded of cellulose acetate butyrate. These savings result from: (1) Labor saving, as compared with the former hand wipe-in painting; (2) more satisfactory sales, since there is no color change from aging, as there was formerly with the white wipe-in paint, and smooth top surfaces are more pleasing to user since they cannot collect dirt. For special application, three and four colors can be molded.



Durez Plastics and Chemicals, Inc.

Replacing a porcelain unit, this transformer tap changer is molded of a phenolic (Durez) plastic. Compared with the former open porcelain changer, the new design is safer, better looking, and costs less. To hold the intricate details to close tolerances, two parts were made by transfer molding and the third by compression molding. New changer allows higher safety standards.

How to Specify an Economical Surface Coating



The Sherwin-Williams Company

Special "Dimenso" finish is applied by simultaneously spraying two heat resistant, air-drying synthetic enamels from one gun. On this product, a small space heater, a light gray background and dark brown "accent" color give the special effect desired.

FINISHES are usually expensive. Spraying synthetic enamel runs betwen 14 and 25 dollars per hour, based on a material cost of 3 to 3.75 dollars per gallon. Thus, selection and application of a finish becomes as important as the design of the original product itself.

The accompanying checklist will give the designer some idea of the number of factors to be considered when specifying a surface coating. It should be noted that some factors – such as those listed in groups I and II – are relatively fixed. The decisions really affecting cost, then, are in the choice of finish and method of application, which in turn often depends on the facilities available in the plant, and comparative cost of sending the work out.

SURFACE COATING CHECKLIST

I. Information on object to be coated

Product or item to be coated .....

Final use of product .....

Composition of product ..... Surface .....
If metal, what kind .....
casting ..... structural
metal ..... sheet metal .....
If wood, what kind .....
Open or close grained wood .....
If plastic, thermosetting or thermoplastic? .....
Composition .....
Other surface .....
What is maximum temperature surface will tolerate .....
Surface condition? .....
Is foreign matter such as wax, oil, or rust present .....
Type of surface cleaning or treatment employed .....

Purpose of coating? Protection .....
decoration .....
functional .....
Is coating applied before or after item is fabricated .....

II. Performance Requirements

For interior or exterior use .....

Resistance to: weather .....
sunlight ..... water .....
salt spray ..... moisture .....
corrosion ..... oil .....
grease ..... fungi ..... marine
growth ..... fouling organisms .....
Heat: temperature .....
Cold: temperature ..... acids .....
alkalis ..... industrial fumes .....
other chemicals .....
abrasion ..... impact .....
marring ..... toughness .....
Properties required:
adhesion ..... hardness .....
non-toxic ..... non-flammable .....
flexibility .....
dielectric strength .....
conductivity ..... non-conductor .....

Miscellaneous requirements .....

III. Physical and Application Requirements

Clear or pigmented coating .....
Which color ..... Type of
coating: oleoresinous ..... lacquer
synthetic .....
wrinkle ..... hammer-effect .....
Specific Gravity ..... Non-volatile .....
Is coating required as a one-coat finish, or as part of a multiple coat system? .....
What primer or undercoats used .....
No. of coats .....
Degree of gloss: Flat ..... Semi-gloss ..... High gloss .....
Consistency? Ready to use .....
If not, what reduction required .....

Coverage ..... Dip-tank stability .....

Drying: Air dry or bake .....
Air dry: Dry-dust free ..... hr
Dry-tack free ..... hr
Dry-to handle ..... hr
Dry to sand ..... hr
Dry to recoat ..... hr
Dry-print free ..... hr
Is force drying used? Time .....
temperature .....
Bake: Maximum time at maximum temperature possible .....
Air dry time before baking .....
Is preheating of product necessary .....

Time before entering oven ..... time to reach top heat ..... time at top heat
Cooling time before handling .....

IV. Production Requirements

Method of application .....
Brush .....
Spray: Type .....
Automatic spray ..... Hot spray
Electrostatic spray .....
Dip ..... Immersion time .....
withdrawal rate ..... inches per min.
Time for draining .....
Roller coat ..... Flow coat .....
Flush coat ..... By squeegee .....
Vacuum impregnation ..... pressure .....
Is conveyor system used .....
Rate of speed .....
Bake methods: Infra-red ..... Convection oven ..... type .....
Other heat source .....
Production rate desired .....

Prepared by Joseph J. Stivale, Brooklyn Varnish Mfg. Co., Inc., Brooklyn, N. Y.

Cost Cutting Hints for Design in Nonferrous Metals

R. Carson Dalzell

Of the common nonferrous alloys, only a few are commonly used for structural or decorative parts: magnesium, brass, copper, bronze, zinc, tin, lead, aluminum, and nickel. These represent a good starting point when making a cost comparison. Others have special applications in a given industry – such as tungsten in the electrical industry – while still others are primarily used as alloying elements or as metallic coatings – such as vanadium or chromium. As a guiding principle in the selection of a non-ferrous material, it is wise to use the simplest alloy that will meet specifications. Aluminum alloys 2S and 3S will fill many requirements, and they are less costly than some of the stronger alloys such as 25S-T or 75S-T.

Standard compositions of all materials cover a wide range of physical and mechanical properties in all metals. Seldom is it wise to specify special compositions because of the additional cost involved. ASTM compositions are a good general guide, although some concerns have their own special grades. It thus is wise to check with various suppliers before making a rigid specification.

Form of material affects initial price. Comparing the cost of one metal against another in sheet form may give an entirely different answer than of comparing the cost of the same materials as forged ingots. Cost comparison must be made on the basis of the form that is to be used – rod, wire, tube, sheet, strip, or ingot.

Size of stock is another factor. Parts should be designed so that they can be made from economical widths if strip stock is to be used. In widths two inches and less, the extras generally increase rapidly.

The question of finishes and tolerances can have a marked effect on cost – and the designer can do something about it. Close tolerances have a multiplication effect; they may cost more than the material itself. The mechanical finish on a sheet stock may be as rolled or polished. If a polished surface is necessary on one surface only, that surface should be indicated so that the other surfaces may be simply commercial quality.

Market price alone is a poor indication of the cost of a material. Comparative properties and the cost of getting the material into finished form must also be considered. Otherwise, a totally erroneous estimated part cost may be the result.

It still is a good idea when comparing material costs to estimate how much the initial cost of the material affects part cost. If this effect is high and there is a marked change in initial cost, it may be cheaper to switch to another metal.

Important new uses are being found for some of the metals that up to now have been considered in the "special" or "scarce" categories. Many have properties that overcome their greater cost. Titanium, zirconium, molybdenum, and lithium are in this category. It is reported, for example, that the shear strength of titanium rivets exceeds that of aluminum by a sufficient amount that two titanium rivets can be used in place of three aluminum rivets in some applications. One manufacturer estimates the cost of making a riveted joint – locating and punching the hole in two sheets plus actually making the riveted joint – at 50 to 60 times the initial cost of the rivet.

An Example

Parts requiring some type of spring property present typical opportunities for saving in design cost. Springs automatically suggest beryllium copper, phosphor bronze, or nickel silver. Perhaps you need the very superior properties inherent in those metals, but be sure of that. Aluminum and brass have good spring properties too, and they cost much less.

The first consideration is "What property do you really want?" Stiffness? What do you mean by "stiffness": (1) Exertion of considerable force with a small deflection; (2) ability to be deflected considerably without taking a permanent set; or (3) to hold a given load over a long period of time? Each problem requires a different solution.

Take a look at spring design formulas. Young's Modulus and physical dimensions determine the resistance to deflection and the stress in the metal. Stress must not exceed the yield strength of the metal – this is a limiting factor.

For condition (1), will aluminum be satisfactory? Because of its low modulus it will have to be fairly thick and possibly wider than you intended. With brass the thickness can be reduced if necessary, or the thickness can perhaps be retained to get extra resistance to deflection. Longitudinal crimps are sometimes used to get extra "stiffness." But is it cheaper to buy thicker metal than to put in the crimp mechanically? Can you shorten the lever arm? Don't make the common mistake of thinking that a harder temper in the same metal will increase its resistance to deflection.

Harder temper might help for condition (2), though, if it raises the yield strength enough. Metal of lower modulus will help, too, provided the yield strength of the hardest temper is not too low.

Condition (3) is a different story; it calls for something special. A metallurgist had better be consulted early in the design stage.

If uniformity of "stiffness" among mass-produced parts is important, dimensions are the governing factor. Remember that resistance to deflection varies as the cube of the thickness.

Commercial finishes available in copper-base alloy sheet and strip are shown on page 155, Reference Book Sheet. Of the twelve finishes listed, only two – polished surface and scratch brushed finish – are furnished at a substantially large extra cost. The other ten are available at a slight or no extra cost, and should be specified whenever possible.

Selecting the Proper Steel*

WHEN CONSIDERING FERROUS METALS, the designer thinks of (1) Cast iron, including nodular grades; (2) hot and cold rolled steel; (3) low-carbon, high-strength structural steels; (4) stainless steels; (5) special high and low temperature alloys; (6) electrical steels; (7) high-alloy heat-treatable steels. While selection of the type and grade of metal is of considerable importance when designing a structure, equally important is part design that will result in such metal being used to best advantage and, therefore, at minimum cost.

Knowledge of the operating stresses and stress concentrations often results in substantial economies. True, the cost of accurate designing may exceed the saving that is realized when only a limited number of bulky items is to be produced, but in most equipment, overdesign cannot be tolerated. The aircraft industry was the first to realize the benefits of precise design, since the decrease in weight and increase in reliability were vital to the success of aircraft. The elimination of unneeded material is of critical importance for other equipment however, in which the strength-weight ratio must be high; even in machinery in which performance is not affected by overdesign, cost usually is.

Pre-stressing of components and structures to obtain longer life and better performance is one technique used to obtain the maximum potentialities of a given material. This is indicated in the chart on this page and will be covered in detail in forthcoming articles in PRODUCT ENGINEERING.

In specifying a material, it is fundamental to either: (1) Specify standard compositions if at all possible, or (2) specify a material on the basis of physical or mechanical properties rather than on the basis of composition. Composition is not necessarily an index of the properties that may be obtained, especially in a casting, since distribution of graphite and the graphite flake may have a significant effect on the properties. Of late considerable work has been done on the specification of steel by hardness rather than composition, and metallurgists have succeeded in relating tensile strength and yield strength to hardness on many different classes of steel. Work now in progress should establish soon if there is a relationship between hardness and fatigue strength, and if so, what it is.

Ordering a steel by the hardness number only or by other required properties can conceivably result in a considerable savings in material cost, since it puts the problem of meeting the specifications up to the metallurgist in the suppliers plant, who knows the standard types of materials and knows how they can be altered at minimum cost to meet such specifications.

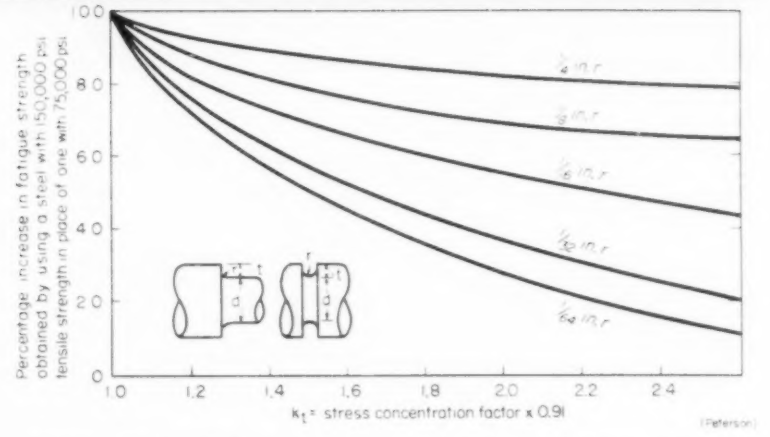
However, the designer should remember that the initial cost of a material is often less important than other factors that enter into the final cost of the part. The type of production process used, the need for salvage operations, or occurrence of high percentage of rejects will affect the cost. For example, one type of steel may be preferred over the other purely on the basis of decreased handling costs. Nitriding, flame or induction hardening, or cyaniding may require fewer operations than carburizing, and thus may influence the type of material selected.

Finally, the class of steel-low-carbon, low alloy stainless, or others – is established on the basis of performance required in the part. But the type may be established on both performance and cost, or even on price alone. There are many different types of stainless steel, for example, and even the austenitic grades, which include the 18-8 composition, contains many different types. The price differential between some of these types and grades is not inconsiderable, and this applies also to the type of finish that is specified if the material is to be in sheet form.

Another example of this is high alloy hardenable steels. In this class there are approximately six ferrous types, as indicated in the accompanying table. The first problem is to select the type. The second problem is to select the specific grade required. Any one of many factors may dictate the choice of one of these particular steels, but assume for the moment that wear resistance is the property of primary importance in a selection. Among the varying factors that have a great influence on wear

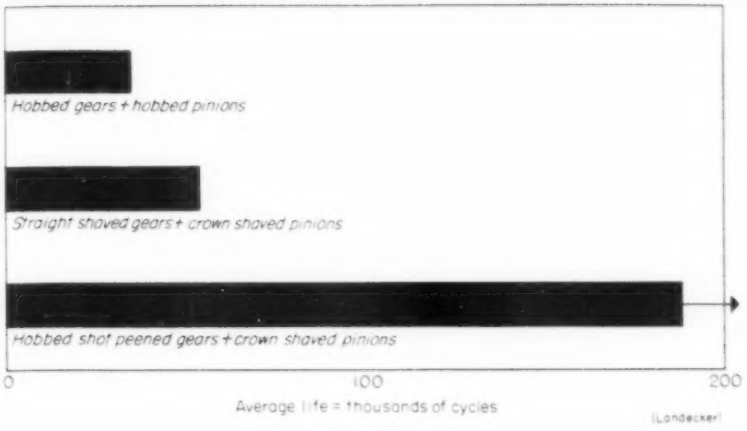
*Data courtesy Climax Molybdenum Co.

Do You Need Extra Strength?



Greater notch sensitivity of stronger steels is shown perhaps more clearly in terms of the decreasing improvement in fatigue strength obtained by increasing the strength of the steel. If notches are present, as in bolt threads or oil holes, little fatigue strength is gained by raising tensile strength above 125,000 to 150,000 psi. To obtain the greatest benefit from high strength materials, stress concentration should be reduced by careful design.

Can Cold Working Substitute for Higher Alloy Steels?



One common way of improving fatigue strength is by the controlled cold working of finished parts. Cold working can be good or bad, depending upon how it is done. For example, cold rolling with a large reduction and cold straightening are generally deleterious since they put the surface layers in tension. Suitably controlled cold rolling or shot peening, however, can produce quite spectacular improvements in fatigue life.

resistance are lubrication, condition of the surface, and type of material with which the part is in contact. Various surface coatings, including electrodeposition as well as chemical coatings, are being used with considerable success to prevent scuffing, galling, seizing and excessive wear during break-in periods, and where borderline conditions exist. Whether such operations or surface hardening of the steel is to be used will influence the material selected.

In general, the wear resistance of steel increases with hardness for equal carbon content, and with the carbon content for equal hardness. A flame hardened steel is likely to have poorer wear resistance than a carburized steel. But this, of course, does not take into account cyanided or nitrided parts, which have better wear resistance than would be expected from the carbon content.

Perhaps the last fundamental for low cost design is to keep abreast of new developments and price changes involving not only material but methods of fabricating and general trends in industry. For example:

(1) *High temperature alloys* — A whole new science has grown up since the war, involving special high temperature alloys for use at temperatures of 900-1,500 F. In many cases, use of such alloys even though they are considerably more expensive than common grades of steel may result in appreciable savings.

(2) *Clad Steels* — Often considerable economies can be effected and better properties obtained by use of a clad steel rather than a solid material.

What Types of High Alloy Hardenable Steels?

TYPE	REPRESENTATIVE GRADES	APPROXIMATE HARDNESS AS USED	GENERAL REQUIREMENTS	TYPICAL APPLICATIONS?
THROUGH HARDENED				
MEDIUM CARBON	AISI-SAE steels with 0.3 to 0.5% carbon	250 to 400 BHN	Strength and toughness	Shafts, miscellaneous forgings, some gears (frequently cyanided), bolts, nuts, flanges, bearing cages
HIGH CARBON	AISI-SAE steels with 0.5 to 0.7% carbon	375 to 500 BHN	Strength, moderate wear resistance	Springs, collets
BEARING TYPE	52100	60 to 64 Rockwell C	High strength, high resistance to wear and scuffing	Bearings, balls, rollers, spacers, pins, bushings
SURFACE HARDENED				
CARBURIZED	AISI-SAE steels with 0.15 to 0.3% carbon	Case about 0.015 to 0.125 in. thick; case hardness over 60 Rockwell C; core hardness up to 45 Rockwell C	Wear resistant case, high endurance strength	Gears, shafts, bearings, inspection fixtures
FLAME OR INDUCTION HARDENED	AISI-SAE steels with over 0.4% carbon	Case over about 0.050 in. thick; case hardness over 55 Rockwell C; core hardness up to 45 Rockwell C	Wear resistant case	Shafts, pins, some gears, cages, bushings
NITRIDED	Nitralloys, also AISI-SAE steels with 0.3 to 0.5% carbon	Case up to about 0.030 in. thick; case hardness 500 to 1000 Vickers hardness (diamond pyramid); case hardness over 30 Rockwell C	Wear resistant case, high endurance strength, some corrosion resistance and resistance to elevated temperatures	Shafts, gears, couplings, bushings

Brazing Costs as Affected by Seven Basic Br

Method and Description	Cost-Cutting Advantages	Expensive Limitations
1 Hand Torch: Gas welding torch burning acetylene, hydrogen, or methane, together with air or oxygen.	1. Flexible method, applicable to a great many assemblies. 2. Equipment is low-cost. 3. Heat can be localized.	1. Work will oxidize. 2. Skilled operator required. 3. Relatively slow. 4. Base metals limited. 5. Multiple or inaccessible joints can't be brazed. 6. Localized heating will cause distortion.
2 Resistance: Heat is supplied to the work by conduction of heat from hot carbon electrodes or, by resistance of work to the passage of current.	1. Short operator training period. 2. Equipment is low-cost and simple. 3. Localized rapid heating. 4. Moderate production rate. 5. Effective for long seam brazes.	1. Individual handling necessary. 2. Distortion is possible. 3. Size of assembly is limited.
3 Radiant Gas Burner: Ceramic burners, using gas-air mixture under pressure, apply concentrated heat to work on conveyors or automatic indexing tables.	1. Unskilled operators can be used. 2. Localized, rapid heating. 3. Controlled heat is ideal for mass production work.	1. Costly equipment. 2. Some distortion. 3. Work oxidizes. 4. Exact temperature control difficult.
4 Salt Bath: Also called Dip Brazing. Work is dipped into molten salt bath to heat. Bath can have fluxing action.	1. Accurate temperature control. 2. Rapid heating. 3. Copper brazing possible. 4. No flux needed for some applications.	1. Fixtures required. 2. Danger of explosion with wet parts. 3. Salt carry over. 4. Parts must be washed. 5. Some oxidation during cooling period.
5 Furnace: Work is heated in a furnace in presence of reducing atmosphere. Filler material is in the form of foil, paste, slugs, powder or molten spray.	1. No residual stresses. 2. Good for mass production. 3. Uniform heating reduces distortion. 4. Control of carburization or decarburization. 5. Bright surfaces. 6. Accurate control of temperature.	1. Requires fixturing or self-positioning of components. 2. Localized heating not possible. 3. Expensive equipment for small lots.
6 Induction: High frequency currents induce eddy currents in the work and produce heat.	1. Rapid, localized heating. 2. Adapted to mass production.	1. Possible distortion due to local heating. 2. Copper brazing not usually practical. 3. Temperature difficult to control.
7 Molten Metal Dip: Parts are immersed in bath of molten brazing alloy.	1. Brazes great many joints at once.	1. Applications extremely limited. 2. Parts must be clean and well fluxed. 3. Bath must be large to keep down temperature drop on immersion.

Brazing and Weld-Brazing Methods

Possible Filler Rods or Materials	Possible Base Metals That Can Be Brazed	Most Economical Applications
1. Naval brass. 2. Brass brazing alloy. 3. Manganese bronze. 4. Low fuming bronze. 5. Phosphor bronze. 6. Silver alloys (with or without phosphorus). 7. Copper silicon. 8. Nickel silver.	1. Steel. 2. Copper. 3. Copper alloys. 4. Stainless steel. 5. Nickel. 6. Nickel alloys.	1. In assemblies where self-jigging is impractical. 2. In assemblies that require extensive fixturing. 3. Small production runs, where inexpensive equipment will offset inherent disadvantages.
1. Copper phosphorus. 2. Silver alloys (with or without phosphorus).	1. Steel. 2. Copper. 3. Copper alloys. 4. Stainless steel. 5. Nickel. 6. Nickel alloys.	1. Where combination of heat and pressure are needed to insure good joint. 2. Small parts, especially electrical components, brazed with silver and phos-copper.
1. Naval brass. 2. Brass brazing alloy. 3. Manganese bronze. 4. Low fuming bronze. 5. Phosphor bronze. 6. Silver alloys. 7. Copper silver. 8. Nickel silver.	1. Steel. 2. Copper. 3. Copper alloys. 4. Stainless steel. 5. Nickel. 6. Nickel alloys.	1. Mass production parts where large parts need not be heated. 2. Silver and phos-copper brazing where parts are on production line basis.
1. Brass brazing alloys. 2. Silver alloys (with or without phosphorus).	1. Steel. 2. Copper. 3. Copper alloys. 4. Stainless steel. 5. Nickel. 6. Nickel alloys.	1. With assemblies that lend themselves to suspension in fixtures. 2. For parts that require rapid heating.
1. Electrolytic copper. 2. Deoxidized copper. 3. Brass brazing alloys. 4. Naval brass. 5. Copper phosphorus. 6. Silver alloys.	1. Steel. 2. Copper. 3. High Copper alloys. 4. Stainless steel. 5. Nickel alloys. 6. Nickel.	1. Widely used for copper brazing. 2. With multiple or inaccessible joints. 3. Mass production where assembly permits fixturing or self-positioning.
1. Nickel silver. 2. Silver alloys. 3. Copper phosphorus.	1. Steel. 2. Copper alloys. 3. Stainless steel. 4. Nickel alloys. 5. Nickel.	1. Applications where the joint is not too deep and components not too heavy. 2. Mass production silver brazing.
1. Brass brazing alloy.	1. Steel.	1. Wire baskets. 2. Assemblies made of narrow metal strips.

Welding Is Cheaper . . .

if it is provided for in the design stage. Here is a list of things the designer should check to get more out of the welding dollar.

1. Design for the use of *automatic welding* machines wherever possible. Check the following points that facilitate machine welding:

(a) Keep welding contours as simple as possible. Complex patterns require expensive machinery.

(b) Confine individual welds to one plane. When welds extend into the third dimension, it is necessary to change traversing speed of electrode and provide lift for the welding unit. In some cases of three dimension welding, it is cheaper to hand weld.

(c) Minimize the number of pieces.

(d) Work with the jig designer to simplify the jigs. Where possible combine operations and reduce the number of jigs required.

2. Make welds *accessible*. The designer should know what the welding equipment available in the plant looks like. Bulky equipment calls for wide open design. Don't make sections so deep as to require a long reach with the electrode.

3. *Orient the welds* so as to minimize movement of the part during welding. It is usually advantageous to rotate a part several times during production so that all welds can be done in the downhand position (this position favors fast and economical welding). Often, the designer can arrange the welds in such a way that all welding can be completed in one set-up of the part. This represents savings in materials handling and welder's time.

4. As far as possible, select *materials* that will not require special welding procedures. Nearly all metals are weldable but some involve more difficult techniques than others. But if a certain material must be used, the designer should familiarize himself with the welding techniques and equipment needed for that material. They should influence his design.

5. Can the design be changed to reduce *plate thickness*, yet maintain strength requirements? Heavy plates require proportionately more weld metal, hence cost more to weld.

6. *Don't weld everything* —

(a) Use methods of forming (the bending brake for example) to eliminate some welds. The designer should know the equipment available in his plant for such forming.

(b) In designing non-standard structures, try not to weld the whole assembly from plates. Perhaps standard structural shapes (angles, channels, I-beams, formed heads, etc.) can be used in fabricating a special shape with a consequent reduction in the amount of welds required.

(c) Some welds are difficult to make and, hence expensive. If production run is small, it may be cheaper to adopt some other method of construction.

7. Don't use too few pieces. It is often cheaper to weld together several small castings than to use one big casting. Also, a piece welded from several simple stampings may cost less than a single deep drawing.

8. The most economical joint is that which requires the minimum of deposited metal and the least edge preparation. Ordinarily, the designer has several types of joints from which to choose, all capable of carrying the calculated load. Before specifying any one type, he should estimate the costs for both edge preparation and welding.

9. In hand welding especially, a series of short welds may be cheaper to make than one long continuous weld.

10. Don't overweld. Any amount of weld metal in addition to that needed for the specified strength means money wasted.

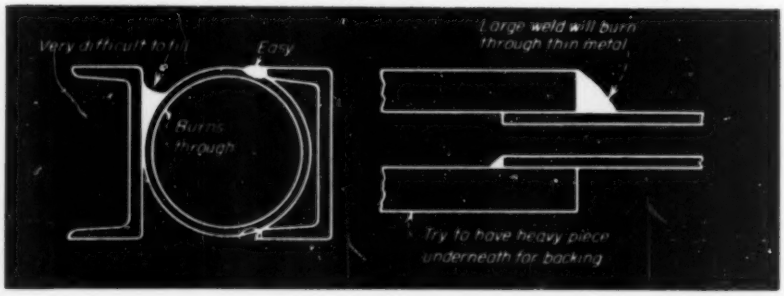
11. Grinding and finishing are expensive operations. If appearance is vital, try to put the welds where they won't show.

12. Correct design can limit distortion of metals from welding. This will mean savings in post-welding machining and straightening.

(a) Use small welds.
(b) Use intermittent welds.
(c) Minimize weld metal needed.
(d) Place welds near the neutral axis.
(e) Arrange welds so as to balance one shrinkage force against another.
(f) Design fixtures with ample strength and support to control distortion.

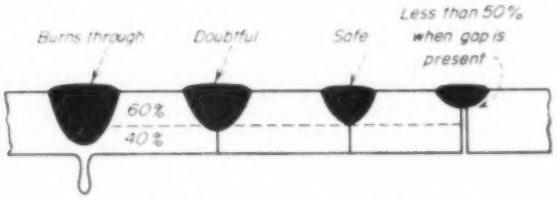
13. A small continuous weld can produce strength equal to that of a large intermittent weld. Six inches of ¼ in. fillet weld is as strong as three inches of ½ in. fillet weld. But the ¼ fillet requires much less metal and can be welded at twice the speed.

Sometimes simple design changes, such as those sketched below, make possible a cheaper joint without sacrifice of strength.

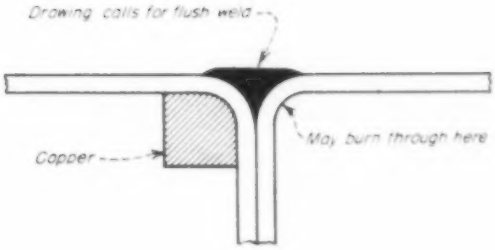

Very difficult to fill
Easy
Burns through
Large weld will burn through thin metal
Try to have heavy piece underneath for backing

Above data courtesy of The Lincoln Electric Co., The Linde Air Products Co., The Hobart Brothers Co. Illustrations courtesy of The Lincoln Electric Co.

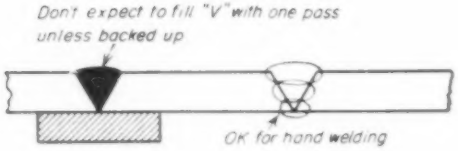
In using machine welding, the designer must consider depth of penetration. If a very deep penetration is specified in one pass without backing, the work will burn through. This problem can be solved either by specifying one pass on each side or by calling for backing.

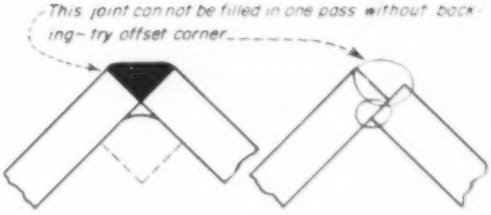


About 60 percent penetration is all that can be safely obtained on one pass without backing. Even less when gap is present.

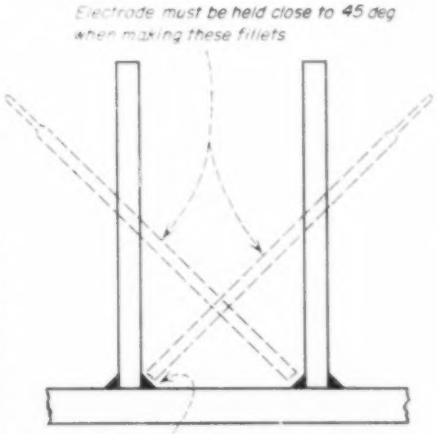


This is to much weld metal to fill in one pass on thin metal. Cooper backing is needed or multiple pass.

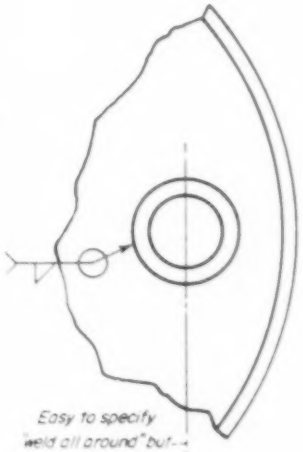


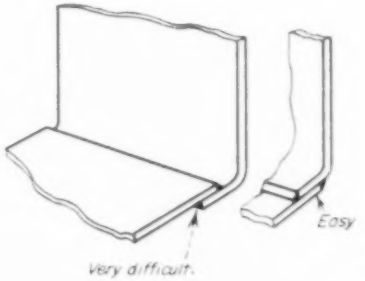


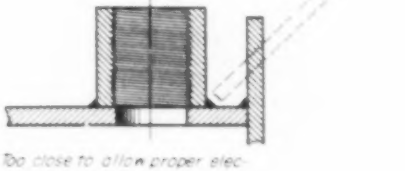
Welds should be made as accessible as possible. Hidden welds are difficult to make accurately. Also, they are costly because of the increased welding time involved. A good practice for designers is to visualize the welding equipment each time he specifies a welded joint.



Easy to draw – but the 2nd weld will be hard to make







Too close to allow proper electrode positioning – may be OK for average work but bad for leakproof welding

There's More Than One Resistance Welding Method

Spot – High amperage current at low secondary voltage applied to parts through small electrodes melts parent metal, which when cooled forms into a "nugget." Pressure applied to parts both during and/or following welding cycle.

Advantages: Fast production, little distortion. Redesign often not necessary. Equipment is semi-automatic or automatic in operation, and in some cases is semi-portable. Does away with bolts, screws, or rivets. No flux required. Good Appearance.

Limitations: Not suitable if a single weld is used and is subjected to torsion. Limited to parts having total thickness of about 2 in. (both parts). Flanges or overlaps required on most parts. Machine requires high capacity power supply.

Applications: For joining thin to medium thick parts either of similar or dissimilar metals, or for "tacking" assemblies prior to furnace brazing or arc welding. Cabinets, sheet metal assemblies, equipment frames, etc.

Series Spot – High amperage current at low secondary voltage applied through electrodes connected in series melts parent metal beneath each electrode and forms series of welds. Pressure applied both during and following welding cycle.

Advantages: Several welds made simultaneously with one movement of machines, either on one assembly or on several assemblies. Minimum amount of sparking. As with spot and projection welding, joint can be tempered on the machine following welding, by the addition of an inexpensive auxiliary control.

Limitations: Requires welder with higher KVA rating than spot welding method. Not suitable for parts with heavy cross sections (greater than ⅛ in. thick). Sometimes not feasible for dissimilar materials with different thicknesses because the thinner sheet limits the amount of current.

Applications: As replacement for special hydromatic (sequence) welders in many instances because lower cost and versatility of machines makes possible more frequent model changeovers.

Projection – High amperage current at low secondary voltage flows from dies or electrodes through projections previously formed on one of the weldments. At these points, the parent metal is melted, and welded, on cooling, due to pressure.

Advantages: Several welds can be made simultaneously. Projections can often be used to locate the parts. Parts are not marked or deformed as much as by spot welding. Fast. Little distortion. Sometimes suitable for joining plated parts. No flux required.

Limitations: Usually not suitable for boxes or cabinets because of size and shape of dies or electrodes. Requires tooling to form projection unless projection is natural (line or point contact between parts); and it may not be feasible to form projections on parts greater than ¼ in. thick. Not suitable for materials with good electrical conductivity, such as copper or aluminum. Most machines are special and high production is required to justify tooling cost.

Applications: When several welds must be made within a concentrated area, to weld fasteners, or to join parts having natural projections.

Upset or Butt – High amperage current at low secondary voltage first applied from electrodes through butt ends of two members in firm contact. When metal at these areas is plastic, heavy pressure forces parts together.

Advantages: Quick method of joining tubes, bars, wires, and small metal sections. Joint can be chipped or machined flush without affecting strength of weld. Suitable for parts of different cross section size, and for joining some dissimilar metals.

Limitations: Machine requires more maintenance than other types of resistance welders except flash because of fumes and high upset pressures required. Usually limited to parts made of aluminum, copper, or mild steel. Power requirements must be low, so section size is limited. Electrodes should contact parts ahead of openings or projections.

Applications: For automatic wire and tube welding, or joining of small sections with low power requirements.

Flash – High amperage current at low secondary voltage applied from two electrodes or dies and then flashes across butt ends of two members separated by a small gap or in light contact. When metal at joint becomes plastic, heavy pressure forces parts together to solidify weld.

Advantages: Quick method of joining tubes, bars, wires, and light sections; usually faster than butt welding and more adaptable to parts having larger cross sections. Otherwise, same advantages of butt welding apply.

Limitations: Machine requires more maintenance than other types of resistance welders. If cross section size is large, part may have to be tapered to reduce initial voltage requirements. Also, weld strength is higher than butt, power consumption is less, and upset is smaller.

Applications: For automatic joining of tubes, sheets, wires, or bars, usually of copper, aluminum or mild steel. Appliances, tanks, continuous sheet or strip, and wheel rims.

Seam – High amperage current at low secondary voltage first applied to parts through circular electrodes melts parent metal and forms series of overlapped spot welds or series of non-overlapping welds (depending on timing) as work is passed beneath or between the electrode disks.

Advantages: Fast. Usually automatic feed and weld. Pressure tight seam can often be formed easier than by other methods. No flux required. No weld bead visible, although there is some marking of joined members by electrodes or wheels.

Limitations: Justified only for high production items. A large volume of water, applied externally, is often necessary to keep the wheel cool, and welding under water is advisable on small parts manufactured in sufficient volume to justify this special set up.

Applications: Large sheet welding, tube welding, and similar products manufactured in large volumes that are especially adaptable to automatic feed. Some small parts requiring continuous seam.

1. Definitions do not conform to those of AWS. See third edition, AWS Welding Handbook.

Tubing for Hydraulic Circuits

L & L Manufacturing Company.

Standard and special design tube fittings that simplify piping problems.

1. Factors to be analyzed

(a) Economy of Space. Good bending qualities and small outside diameter of tubing permits making up connections in close quarters, thus saving space required for installation.

(b) Ease of Fabrication. Seamless tubing is readily bent to required radius. Cost for threading is not an item when tubing connectors are used to make up joints.

(c) Installation Costs. Angle turns are made without fittings; bends are used instead of fittings. Few fittings mean few joints.

(d) Weight. When tubing connectors are used no extra wall thickness is needed for threading, thus saving the cost and weight of excess material.

(e) Pressure Drop. Absence of abrupt changes in direction of flow when tubing is used for hydraulic line promotes streamline flow, thus turbulence of fluid is low.

(f) Vibration. Tubing because of the low ratio of wall thickness to diameter is sufficiently flexible to damp out to a considerable extent the transmission of vibrations from one connection to another.

2. Types of Seamless Tubing

(a) Copper tubing and brass fittings are suitable for water, air, and oil. Seamless copper tubing is supplied in coils fully annealed; and in straight lengths, fully annealed or quarter hard.

(b) Steel tubing and fittings are used for noncorrosive fluids such as oil. Seamless steel tubing is supplied in SAE 1010, fully annealed, suitable for bending and flaring.

(c) Stainless steel tubing and fittings are used for many highly corrosive fluids. Stainless steel tubing is supplied in 18-8, fully annealed, suitable for bending and flaring.

3. Fittings.

(a) Standard Fittings. Specify standard fittings whenever possible. From a cost standpoint, it follows that these can be procured at a low price because of large production runs. Another consideration is accessibility from stock for field service requirements.

(b) Special Fittings. Overall cost of piping a hydraulic circuit, considering labor or installation time and number of fittings required, may sometimes be substantially reduced by the use of "off standard" couplings. These may simplify the piping arrangement so as to avoid awkward changes in direction of tube line. They may even permit installation of a run where space limitations would dictate enlarged machine bases or castings, or rearrangement of other equipment in order to pipe the circuit with standard fittings.

Special fittings may also make unnecessary the use of bushings, unions, and nipples, thus saving their cost, and provide a circuit having a minimum of joints. Special fittings often can be made up by brazing in additional tube outlets in standard parts.

4. Layout and Installation

(a) Arrange tubing lines to assure the operator freedom of action.

(b) Avoid points of interference and obstructions such as working space for machine and work movements, contours of machine, access doors, operating controls, machine parts the position of which may be changed by operating adjustments, and parts that may have to be removed for maintenance.

(c) Layout path of tubing to avoid possible abuse from moving equipment, from carelessness of workers or from other external sources.

(d) Avoid laying out runs from point to point in a straight line, as it is next to impossible to flare the tube to the exact length. If a straight length is shorter than exactly required, the flare will be pulled from its seat when the nut on the connector fitting is tightened. Also, a straight length of tube provides no opportunity for expansion and contraction with temperature change.

(e) Provide adequate radius for bends.

(f) Minimize number of fittings by making maximum use of bends.

(g) Supply proper support for long runs of tubing. Under normal conditions, it is recommended that tube lines be as short as possible, with 5 ft as a maximum length.

(h) Supply adequate support at flexible hose connections so that hose motion is not transmitted to tubing.

(i) Supply proper support where accessories such as valves and other heavy units are mounted.

(j) Group lines for neat appearance, economy of space, and simplified multiple supporting. Bear in mind that individual lines must be located for easy removal if necessary.

(k) In flexible hose applications, remember that metal end fittings cannot be considered a part of the flexible assembly.

(l) Use elbow fittings to avoid horizontal hose connections where the weight of the hose puts an extra strain on the assembly.

(m) Do not use bend radii for the hose less than the minimum recommended.

(n) Keep hose short enough so that loops do not get caught in equipment.

(o) Use swivel tube nut connections for easy assembly and disassembly without twisting hose.

Hydraulic Systems and Elements

So many factors are involved in the design of hydraulic systems that it is impossible to suggest more than the salient ones in any given article. In general, the following factors should be analyzed when considering hydraulic power and control.

1. Design Factors

(a) Simplicity of installation and low weight.

(b) Flexibility of control. Can be controlled remotely either hydraulically, electrically or mechanically. Full range of speed control is accomplished without mechanical adjustment.

(c) Low maintenance costs.

(d) Working mechanisms are fully inclosed, sealed and protected.

(e) Power is applied at required point.

(f) Gear trains and linkages are not required for the transmission of power.

(g) Either linear or rotary motion can be produced.

(h) Complete, compact, packaged units incorporate all or most of the components needed for a wide variety of applications. Their first cost is usually more than justified by savings in engineering, installation, operation and maintenance.

2. Circuit Design

(a) Save with quantity purchases. Standardize as much as possible on common parts throughout the circuit. Use standard manufactured parts wherever possible, unless the quantity of specially designed units required is sufficient to secure production economies or first cost will be justified by savings in installation and maintenance costs.

(b) Installation costs are low when the system comprises only a pump with built-in valves and controls and a cylinder that requires only two pipe lines.

(c) Maintain a proper balance between the life expectancy of the hydraulic system and of the component parts of the driven machine or equipment. Well-built and designed hydraulic elements are not the least expensive on the basis of initial cost but they may reduce final overall cost.

(d) Design for ease of installation, operation, servicing and maintenance.

(e) Place the equipment where protection is afforded from damage and exposure to dirt and moisture.

(f) Select component elements on the basis of maximum load requirements. On load lifting equipment, design to required lowering speed as well as for lifting speed.

(g) Final operating and maintenance costs are influenced by the frequency of high pressure peaks and shock loads that can result from rapid valve changes and rapid changes in direction of cylinder motion.

(h) For the same output power requirements, high pressure equipment is smaller in size than low pressure equipment, but more precaution must be taken to prevent leaks, particularly at pipe or hose fittings. Since high-pressure systems do not require parts of large diameter, parts that have a large ratio of length to diameter should be checked for column strength and buckling deflection under load or thrust.

(i) Accumulators are loaded during stand-by time and during periods of the operating cycle when oil requirements are at a minimum. They also compensate line leakage. Accumulators often make possible the use of a small pump and low horsepower motor unit, and a sump tank of small capacity.

3. Pump Selection

(a) Factors that determine size and type of pump are: Power requirements of load cycle such as constant, repetitive, or intermittent operation; constant or variable speed; constant or variable output power per cycle of operation; and type of power take-off or power source available.

(b) Pumps are built in several standard types of constructions such as: Gear-type, vane-type, reciprocating-piston, axial-piston, and radial-piston. Pumps are designed for constant discharge; high-pressure, high volume, constant discharge; and variable and reversible discharge.

(c) Some types of pumps are designed as integral parts of complete compact power units. These units incorporate in their design many components that reduce first costs by simplifying the engineering and installation of a hydraulic system. These components include oil reservoir, high and low pressure pumps, feed control valves, feed and back pressure relief valves, solenoid actuated directional operating valves, remote pressure control valves, breathers and filters.

(d) Special mountings and adapter shafts, when quantity required is large, may reduce installation and maintenance costs.

4. Valve Selection

(a) Reduce maintenance costs, back pressure and over-heating by using valves of sufficient capacity.

(b) Sectional valves may be used where the number of cylinders used may be increased by the addition of accessory equipment in the field. Provide space for mounting of the additional valves if contemplated.

(c) Block type valves, for some machines, are usually less expensive to install if no change in the hydraulic circuit is contemplated.

(d) Long runs of pipe or hose can sometimes be reduced by placing the control valve near the cylinder or

pump and controlling the valve from a remote position by solenoids, mechanical linkage, or cable.

(e) Control panel units, which consolidate a number of controls into a single package, reduce engineering and installation costs, reduce the number of pipe joints and improve the appearance of the machine. Different combinations of on-and-off valves, metering valves and directional controls are obtainable in such hydraulic control panel units.

(f) Unitized design of hydraulic controls can be developed by using gasketed hydraulic valves and elements. These can be mounted on pads on the machine frame or on subplates.

5. Cylinder Selection

(a) Use manufacturers' standard cylinder mountings to reduce cost and facilitate service and replacement.

(b) Consider use of telescopic cylinders where savings can be made by reducing the space required for mounting.

(c) Avoid use of double-acting cylinders where time of operation is not important and the dead load is sufficient to return the cylinder or plunger; in such events use a single-acting cylinder.

6. Tank Design

(a) Use commercial or prefabricated tanks in place of specially designed units.

(b) Utilize space inside of structural members for an oil reservoir provided it is accessible for cleaning.

(c) Place tanks high enough to facilitate draining and cleaning.

(d) Baffles and proper placement of discharge pipe into the tank will reduce foaming and permit use of smaller tanks.

(e) Breathers and air filters that keep out dirt will reduce maintenance costs.

(f) Tanks should be adequately sealed to prevent entrance of dust, grit, and foreign fluids that when entrained in the oil cause malfunctioning of control valves and pumps.

(g) Provide adequate tank capacity to maintain a low velocity flow of oil between the return line and the pump suction.

(h) Locate return line and suction line as far apart as space permits. Separate these lines with a baffle.

Economical Design of Pneumatic Systems

THE DESIGNER of pneumatic circuits knows that – contrary to public belief – air is not free. In fact, the cost of air is a factor that should influence the selection of the components of a pneumatic circuit, whether for power or control service. For example, a work cylinder designed for 105 psi is smaller and cheaper than a cylinder for the same work force using 90 psi air. However, the saving in cylinder cost does not offset the increased cost of air for operation.

Thus, the designer continually must make compromises between air cost and component cost. Before starting design of a pneumatic system, it is well to estimate closely what the cost of air will be and to keep that figure in mind throughout. Other points to be watched are as follows:

1. Avoid right angle fittings in air lines at they cause considerable frictional loss.

2. Provide protection against leakage. Even the smallest leak may waste many dollars per day.

3. Locate valves and pumps as close to the load center as possible. This will mean shorter branch runs of wires and pipes; lower leakage losses and less maintenance.

4. Arrange pipe, tubing and outlets to minimize lengths of air hose required. Air hose should be no longer than 6 to 10 feet.

5. Be generous with filters and dryers to protect air motors and cylinders. Savings gained by using insufficient filters and dryers is reflected in the customer's repair bill.

6. If additions or changes to the pneumatic system might be needed in the future, use spring chuck type fittings with built-in valves. These permit extra lines to be plugged into the existing systems. Try to estimate any additional air power requirements and provide a pump large enough to supply them.

7. Provide sufficient air volume as well as pressure. It is false economy to use small main feed lines for air. The efficiency of a machine may be seriously affected if mains are not big enough to maintain constant pressure with piston movement.

8. When machine is in use, power losses may build up if maintenance is neglected. Supply explicit servicing instructions for all components.

9. The cost of providing individual pressure gages on all operating elements is often justified. They serve as indicators when trouble develops in the system and give warning of insufficient pressure on air holding devices.

10. If possible, make one lubricator supply the needs of all valves and cylinders. This can be done by locating the lubricator at the inlet of the power line to the main valve.

11. Select tubing size carefully. Tubing that is too small causes frictional losses. Tubing that is too large requires an excessive volume of costly air to fill it.

12. If possible, specify a tubing that can be bent easily to facilitate installation and to eliminate need for elbows and fittings at corners.

13. Make cost comparisons of various pressure systems to determine the most economical system having the required performance.

14. Consider use of a central pneumatic system instead of individual systems for a group of machines.

26 WAYS to Cut Your Wiring Cost

- Many of these tips will result in lower first cost.
- Some will increase first cost, lower maintenance cost.
- Not all are applicable to every machine or piece of equipment.
- But together they represent the latest thinking by machine and equipment builders on ways to improve product quality and reliability.

1. Fork-type connectors can generally be slipped under screw terminals more easily than the eyelet type, thus reducing assembly time. Terminal caps need only be loosened, are not dropped and lost. A tug on the conductor shows up a loose fork connection. Some may argue that a forked-type terminal might loosen and fall off, but a loose terminal can cause as much trouble and require more time to find than one that may have actually fallen from the terminal. The use of a fork-type terminal when making joints (such as in motor terminal boxes) is questionable.

2. Color coding of wires simplifies assembly, improves ease with which circuits may be traced. Some manufacturers use color to designate between various sizes of wire. NEMA standards, however, call for color to be used to differentiate between control and load circuits: Black or grey for line and load wires (a-c or d-c); red, a-c control; and blue, d-c control.

3. New codes of the National Machine Tool Builders call for stranded wire to be used on panels in place of solid wire. Cost is reported to be about comparable, but stranded wire is not as susceptible to shock damage from machine vibration. Also, nicks and bends made during installation have less effect on the wire.

4. Snap clips that can be pushed into punched or drilled holes in the machine base or frame can be used to hold conductors or conduit in position. Many different types are available from the various fastener manufacturers.

5. Identification markers on wires reduce assembly time, since they can be used to show what the wire is, where it comes from, and where it goes. Some solderless connectors are available with these identification markers as insulating sleeves, and many manufacturers have their own equipment for marking and cutting Vinyl tubing.

6. Unitized terminal blocks that are supplied or built up to handle a large number of connections are easy to mount, reduce the amount of drilling required on the panel, localize all connections.

7. Any one of four methods of wire termination can be specified: soldered connectors, indented solderless connectors, pre-insulated solderless connectors, or screw-type connectors. The soldered connector is easy to make and first cost is low. One concern however found that the installed cost ran about 68 percent greater than the solderless type. Another disadvantage to the former type is that it is difficult to tell whether the joint is good or bad. Present standards prohibit the use of soldered connectors on machine tools.

Screw type or special clamp type connectors are used primarily to connect the machine to a power line. Lines equipped with such connectors can be disconnected with a minimum of trouble.

8. Pre-formed wiring for large control panels usually is a big cost saving technique, but it usually is not practical to cut to length, bend, and stock solid wire for use on panels. In such cases, the number of wires required can be formed together and installed on the panel. Harness wiring, Fig. 1, usually is used exterior to control panels.

9. Taped wiring usually is for conduits and braided wiring for cast runways. Taped wiring tends to work loose and become unmanageable in open runways, while braided wire is difficult to pull through conduits at assembly.

10. The possibility of casting wiring raceways into the base of heavy machine assemblies should be investigated. Appearances are improved and wiring becomes an integral part of the product design. While the use of the regular type flexible metallic conduit is frowned upon, the machine tool standards and the Joint Industry Conference Electrical Standards now permit the use of such conduit in cast raceways when the flexible conduit is terminated with regular fittings in proper junction boxes.

11. Wireless wiring diagrams, Fig. 2 are easy to draw, simple to visualize, and may give the electrician a truer representation of the actual connection layout, unhampered by the usual maze of criss-crossing lines, than a standard wiring diagram. Connections should be listed in some form of logical sequence, however, and it often helps both the customer and the shop if elementary diagrams are included for better visual presentation of the circuit. On machine tools, an elementary wiring diagram is required whenever more than one starter is used.

12. Consideration should be given (*A*) to "casting in" the control box for a machine as an integral part of the frame or base; and (*B*) to fabricating the control box as a separate unit that can be prewired and mounted later in the assembly stages. Which is better and lower in cost will depend on the construction.

13. A dribble shelf over a control box is protection against falling machine waste and dirt. Extending the top of the control box a few inches helps prevent accumulations in the enclosure.

14. Frequently controls for one machine can be enclosed in one control box. The control box should be large enough to allow for complete use of disconnect switches, control transformers, and terminal blocks.

15. Sponge rubber, of the oil-resisting synthetic type, or felt padding around control box doors also keep out dirt. Sponge rubber may be a good bet as felt pads may be cut by sharp door edges.

16. Plated screws and metal parts are less susceptible to corrosion and discoloration in control boxes than unplated fasteners. Control equipment life is prolonged with fewer broken and shorted out circuits.

17. If multi-coil control transformers are standard, they can be modified to fit any control unit by means of different wire taps. Standardizing on one control transformer often has proved cheaper than employing a special transformer for each application.

18. Painting the inside of control boxes white instead of grey or black insures better visibility for the electrician when wiring the panel, makes inspection and observation of equipment easier.

19. Many industry codes require moisture-proof seals between holes and mounting studs in control boxes. By using stud welding to fasten the panel

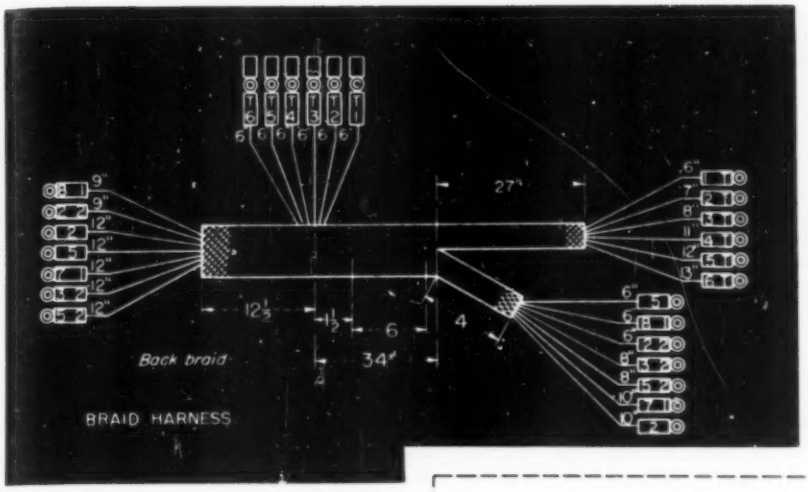
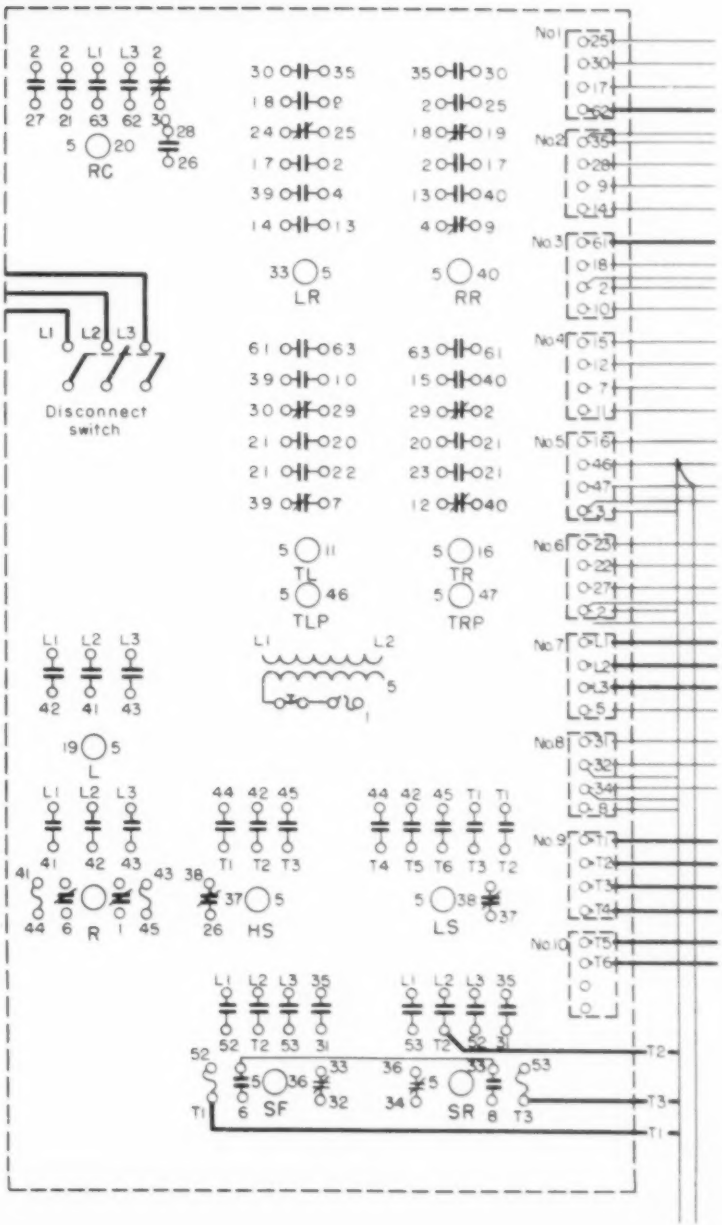


Fig. 1 (Left) — Braid harness. Harnesses of this type can be assembled much faster than if each wire were to be placed on the machine individually and then grouped.

Fig. 2 (Below) — Section of a wireless wiring diagram for a machine tool. The complete diagram shows all terminals and contains a key to show recommended wiring sequence to avoid confusion.



mounting studs to the inside of the control box, the housing is kept intact and no seals are required.

20. Plastic wiring conduits are clean and give a neat appearance. Braided flexible metal wire conduits also can be used for severe abrasive conditions. Although such conduit is more expensive, the extra cost is overbalanced by replacement savings.

21. Resilient mountings for relays and solenoids cut vibration and shock damage to delicate mechanisms.

22. Lock-in screws should be held permanently in panel doors. Permanently anchored screws are not lost at assembly.

23. Avoid overconstraint on mounting panels by allowing generous wire flexure between mechanical elements. The extra wire used is negligible compared to the possible vibration and shock damage to the connected units. However, the greatest hazard where insufficient wire length is involved is the added strain on the wires with resultant breakage.

24. Shell motors improve the appearance of the assembled machine. A shell motor consists of a standard motor rotor, with a special stator assembly, designed to fit surrounding machine parts. Rigidity and vibration problems may be solved by more integral assembly, but cost is higher.

25. Motors can sometimes be grouped on a machine under one set of fuses if electrical codes allow. Tests show that there is no fire hazard provided the control mechanisms are properly housed and maximum fuse size is limited to 200 amps on 250 volts and 100 a. on 600 v.

26. Check industry specifications and local codes before attempting any job. Disregard of this rule can cause embarrassment and needless after-expense.

Data courtesy Aircraft Marine Products, Inc. and Burndy Engineering Company. Special credit is due Mr. A. L. Krause, Brown & Sharpe Mfg. Co. for much of the information and for his help.

Which Electric Motor?...

SELDOM is a motor purchased on the basis of first cost. Only if two or more types or systems meet the exact performance specifications does first cost enter into the picture; this can be determined only by comparing the performances of various drives that might possibly meet application requirements. On the other hand, the mechanical features of the motor may materially affect cost and are generally within control of the designer. He has considerable latitude in specifying the type of mounting, type of bearing construction, method of connection to the load, and other mechanical aspects.

There are no general rules for motor selection. Each machine must be individually analyzed and the motor selected on the basis of performance first and cost second. However, some points can be made regarding cost.

1. Whenever possible, an a-c squirrel cage motor should be specified in preference to any other type, including d-c, since it is the least expensive and requires less maintenance. Doing this will eliminate the high cost of end shielding, wound rotor construction, or brush maintenance.

2. Flange mounted motors are generally less expensive than foot mounted motor in fractional horsepower types, since the flanges can be machined in the same set up as other turning operations. Secondary milling operations are necessary for foot mounted units. In integral horsepower sizes this situation is reversed.

3. The higher the motor speed, the lower the cost per horsepower because the same power is obtained in a smaller motor. The smaller motor has less material in it, and therefore is less expensive (below 75 hp).

4. The larger the motor, the less the cost per horsepower. However, the designer should remember that there are penalties for overmotoring – excessive inertia, added power consumption and slow response.

5. Non-standard specifications – whether electrical or mechanical – should be avoided whenever possible. Specials cost money, no matter how insignificant.

6. Mounting and ventilation should be such that the motor does not run hotter than required for standard class *A* insulation. Otherwise the more expensive class *B* insulation is necessary.

7. Actual torque requirements for satisfactory operation should be specified. No factor of safety is necessary above the normal one for voltage fluctuations or variations in the driven mechanism. Smaller output requirements might make possible a smaller and less expensive motor.

8. Sufficient space should be allowed in the machine for the motor and auxiliary. Otherwise a special condensed motor design is necessary.

9. The motor and its control should be considered as a unit. It is possible to select a low cost motor that will need an expensive control if the required performance is to be obtained. The price of the control may more than offset any savings in motor cost.

Power Supply

In making a motor selection analysis, power supply is the starting point. Type of power–a-c or d-c–frequency of supply, number of phases, and line voltage must be established. If the motor is to be fitted into an existing system, little work is involved. But if the system itself must first be established, (as for a marine or aircraft installation, for example), the converse is true. In this latter case, not only performance characteristics of the system, but also the availability of components in the required types and sizes are governing factors.

Performance Characteristics

Performance characteristics of the drive come next in the analysis, and one of the first considerations is whether the motor is to be a constant speed unit, stepped speed device, or adjustable speed drive. Stepped speeds can be obtained by: (1) connecting the motor through a mechanical stepped drive, such as a stepped cone pulley; (2) using a fluid coupling and jogging the motor, provided the motor is small and the speed does not have to be held with close limits; (3) using stepped gear drives, as on machine tools; (4) specifying a squirrel cage, two-speed motor; (5) specifying a squirrel cage, 4-speed motor, in which case alternate speeds should be multiples (600, 900, 1200, 1800 rpm) to get away from special and more expensive windings; or by other special and less common methods. (See "Motor Driven Machines," PRODUCT ENGINEERING, March, 1948, and "Speed Control for Electrical Drives," PRODUCT ENGINEERING, January 1949).

Infinitely adjustable speeds can be obtained: (1) by mechanical transmissions, to a limited extent; (2) by wound rotor induction motors within narrow limits (2 to 1); (3) by standard d-c motors operating off d-c power; or (4) by special a-c d-c converter drives. If d-c power is available, and the speed range need not be over 8 to 1 maximum, a standard d-c motor can be employed. If only a-c power is available, or if the speed range must be greater–as high as 50 or 100 to 1 – drives utilizing special control equipment and an m-g set, thyratrons, ignitrons, or dry-plate rectifiers to convert the power must be used. It is, of course, imperative to know the speed-load characteristics required of the drive. As might be expected, the more severe the requirements, the more costly is the drive. Also, d-c motors in sizes of 1 to 15 hp average almost twice the cost of comparable squirrel cage, a-c motors – a differential that exists in most size ranges. Wound rotors having an inherently more expensive construction and more complex and

Table I — Required Data in Motor Specification

ELECTRICAL REQUIREMENTS	MECHANICAL CONSTRUCTION
Rotation	Mounting
Min. Starting Torque	
Min. Pull Thru Torque	Enclosure
Min. Breakdown Torque	Shaft Ext. Diam
Test Load Time Temp. Rise C	Length
Test RPM	Keyway or Flat (size)
Speed Limits	Endplay
	Finish
Dielectric Test	Nameplate Location
Quietness Test	Leads Length
	Number
Max. Locked Rotor Current	Location
Duty %	
Max. Cont. Running Time	Type of Outlet
Inherent Overcurrent Protector?	Diagram with Motor
Manual or Automatic Reset?	Bearings
Frame (type and size)	

Volts Phase amps

Hp Rating Cycles rpm

Time Temp. Rise C

Remarks

costly controls are more expensive than any of the various classes of squirrel cage types.

If a constant speed drive is all that is necessary, the designer can select the type required on the basis of performance characteristic curves. For d-c operations in integral horsepower applications, series, shunt, or compound wound machines are the standard types. For a-c operation, wound rotor or squirrel cage types are commonly specified. Synchronous machines also are a widely used a-c type in large frame sizes or for small fractional drives for instruments and controls, but cost and excitation requirements generally limit their application in integral horsepower ranges to above 75 or 100 horsepower.

In integral hp sizes, a squirrel cage a-c motor is the cheapest type that can be specified and requires less maintenance than most of the others. If a squirrel cage machine will meet the drive performance requirements, it should be the one selected. Of course the class of squirrel cage motor specified also affects cost. NEMA types *A*, *B*, *C* and *D* are the general classifications. NEMA class *B* is the workhorse of the group and is the one supplied by the manufacturer unless the designer specifically states otherwise.

Regardless of the type of motor, the higher the operating speed, the more power that can be developed in a given space, the less material required to make the motor, and therefore the lower the cost. Also, the larger the motor, the less its cost on

a per horsepower basis, especially in the 1 to 50 or 1 to 75 hp ranges.

Mechanical Factors

Mechanical factors having the greatest effect on motor cost are bearing construction, type of mounting, actual frame construction of the motor, type of enclosure, and method of connecting the motor to the load. Except in very large or very small motor sizes, the type of bearing specified has a rather insignificant effect on the cost of the motor. Power motors in frame sizes of from 203 to 505 show no difference in initial cost, and an advantage gained by ball bearing construction is that the motor can be wall mounted, ceiling mounted or floor mounted without affecting motor performance.

There is some difference in price between a flange mounted motor, a foot mounted motor, a motor with a machined mounting, and a motor with a vertical mounting. This difference varies with motor frame size, but for 15 hp units a motor with a vertical mounting is approximately 30 percent more than one having a foot mounting. For sub-miniature motors, a flange mounted motor is less expensive than a foot mounted unit. Flange mounted motors, of course, can generally be located more accurately than foot mounted units. Because of that, belt or chain drives or flexible couplings usually are used between the motor and load on the latter types.

Special construction of the motor, such as a fore-shortened frame to fit into a limited space, a small diameter motor to fit inside a pump, or a vertical hollow shaft unit for special fluid pumping applications necessitates special tooling and raises the cost.

The type of enclosure is another factor affecting motor cost. The cheapest motor, of course, is the open type. Progressively more expensive are the drip proof, splash proof, totally enclosed, totally enclosed fan-cooled, and explosion proof. Occasionally a totally enclosed fan-cooled unit is more expensive than an explosion proof. Again allowance must be made for special motor types, sizes and ratings.

Other Electrical Features

Motors with special electrical characteristics can sometimes prove more economical than standard units, or may be the only type of machine that can meet performance requirements. A torque motor is an example. Manufacturers who specialize in such construction should be checked for prices so that the units can be compared with standard types.

While the class of insulation also has some effect on cost, this usually is in the province of the manufacturer. Providing adequate cooling parts in the structure of a machine for air to circulate around the motor, however, may mean the difference between class *A* insulation and class *B* insulation, which is more costly. Considerable development has been done in the past few years with high temperature silicone insulated motors that will operate at temperatures up to 200 or 250 C without deterioration. While the cost of a motor so insulated is high, the space required for it is much less than for a standard motor. It is entirely possible to pack a 15 hp motor into a 5 hp frame, provided that the insulation is capable of withstanding additional temperatures.

It should be remembered, also, that the type of motor starter and control used may have a greater effect on overall cost of the drive than the list price of the motor.

While 60-cycle, a-c power is generally accepted as standard in this country, higher frequency may prove more economical in aircraft, where 400-cycle systems are quite common, or for marine applications, where much work is currently being done on higher frequency electrical devices. Even for some industrial applications a high frequency converter and motor drive may prove less bulky, costly and heavy, and may be a better solution to a complex application problem than a standard 60-cycle machine with a gear drive when substantially higher speeds are necessary.

In so far as the number of phases are concerned, this too is governed mainly by the existing system. The plain single-phase a-c motors are usually limited to household uses and farm equipment.

Basic Evaluation of Electrical Motors

1. Does voltage, frequency, number of phase of the equipment, and other basic electrical conditions match that of the system? Could better or less expensive results be obtained by providing conversion equipment?
2. Are electrical characteristics best that can be obtained at the price and compatible with application requirements? Does the torque characteristics of the driving equipment match that of the load? Has machine inertia, including that of the driving motor and transmission equipment, been considered? Has both type and class of motor been checked?
3. Could savings be made by overmotoring the equipment and eliminating transmission equipment, or by undermotoring and using a slip-type coupling that would allow motor to come up to speed immediately and bring the load up slowly?
4. Have all possible control methods been analyzed? Could one starter be used for two motors, with overload protection for each? What starting current limitations must be met?
5. Has horsepower rating and speed been checked on the basis of cost per horsepower? Would two motors instead of one do away with expensive mechanical transmission equipment?
6. Have all possible methods of connection to the load been analyzed? Would flexible belt or chain drives eliminate accurate positioning of elements and speed up assembly?
7. Would gearmotor, brake motor, assembly with integral fluid clutch or hydraulic coupling be less expensive than a standard motor with external accessories?
8. Is it necessary to hold the load if the power supply fails? Is control equipment so designed that the circuit would fail in a safe manner?
9. Is size, weight, noise level a factor in the application?
10. Can motor and controls be economically maintained?
11. Have mechanical aspects of the drive been considered? Are mounting, bearing type, class of insulation, type of enclosure, frame size, and other mechanical features least expensive, consistent with application requirements?
12. Will the equipment meet specifications of electrical testing laboratories? Will it meet code requirements in section in which it is to be used?

Data courtesy:
Westinghouse Electric Corporation
The Electric Products Company
Holtzer-Cabot, Division of National Pneumatic, Inc.
Allen-Bradley Company

TECHNICAL NEWS

Lightweight Gas Turbine Powers 10-Ton Truck

PRELIMINARY ROAD TESTS of the world's first gas turbine-powered truck, using an experimental 175 hp lightweight turbine, have been completed by the Boeing Airplane Co., builder of the turbine, and the Kenworth Motor Truck Corp., builder of the chassis.

During the first three weeks of operation, the truck was driven several hundred miles on highways adjacent to the Boeing and Kenworth plants at Seattle, the longest single trip being a 50 mile round trip from sea level to an elevation of 445 feet.

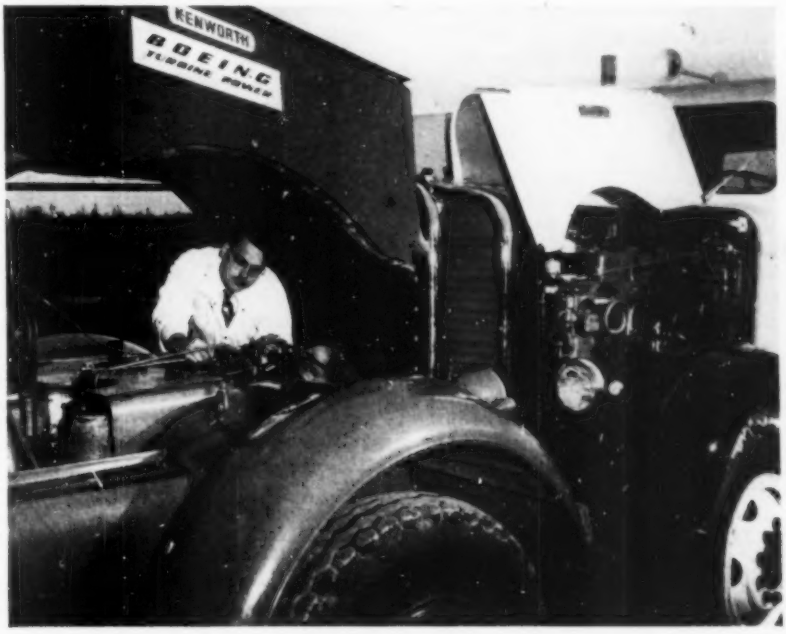
Trial runs of the 200 lb power plant were carried out in a 10 ton truck chassis, sometimes with a 5 ton trailer. Next, the turbine-powered truck is expected to carry heavy loads across the Cascade Mountains as a further test.

William M. Allen, Boeing president, cautioned that "much additional testing and proving have yet to be completed" and emphasized that a comprehensive program of service testing must be carried out before the turbine is ready for production for the general market. So far, however, the program has gone much faster and more easily than Boeing has expected, and some quarters feel that commercial application of the turbine may be closer at hand than previously has been thought possible.

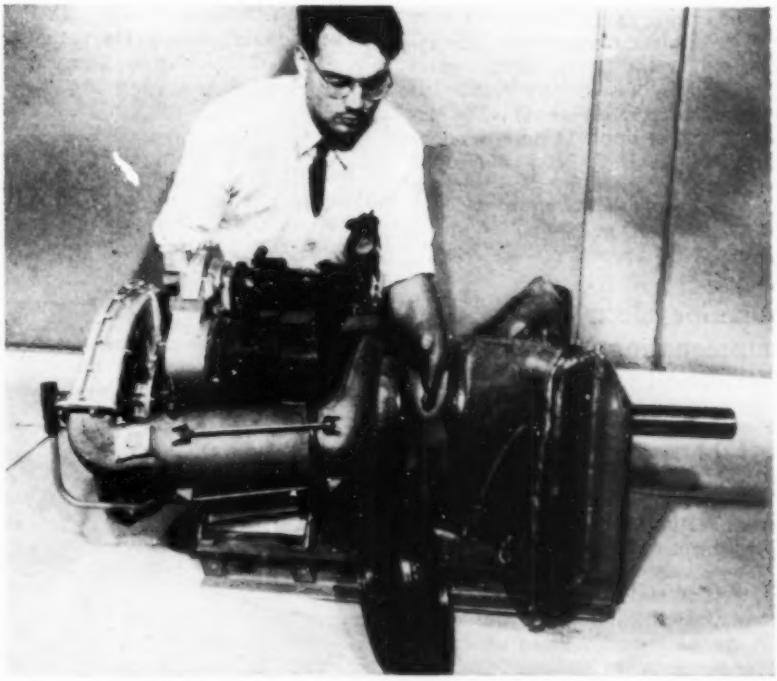
The new truck has proved to be considerably quieter than a conventional diesel truck of equal power, even without mufflers on the twin exhausts which rise on each side of the cab. A silencer on the air intake, just below the bumper, leaves only a thin whine as compared to the throaty roar of conventional engines.

Exhaust gases are about the same temperature as those from a diesel or gasoline truck, Boeing engineers said. At idling power, for instance, it is possible to place a hand over the end of the exhaust pipe without danger of being burned. Exhaust gases are virtually invisible, except for a puff at starting, and have no offensive odor.

The truck so far has been operating simply with a three-speed auxiliary rear-end transmission and a marine re-



IDENTICAL KENWORTH MOTOR TRUCK CORP. UNITS, powered by new Boeing Air plane Co. 175-hp gas turbine, left, and diesel power plant of similar rating, right, are compared above. Adjusting new gas turbine is Lloyd Hill, a Boeing project engineer who drove truck during most of its road tests, although he never had driven a truck before. The new engine uses only 13 percent of the usual engine space.



THERE IS NO MECHANICAL CONNECTION between the power-producing section (left) and power-output section of the Boeing gas turbine. Only connection between the two sections is shroud which man is installing. The power-producing section puts out a blast of hot gases which drives the rear section.

verse gear, but Pacific Car & Foundry Co., Kenworth affiliate, is known to be working on an automatic transmission. Since the turbine eliminates much gear shifting, the new transmission would require much less than the 12 to 15 speeds now required. With the present auxiliary transmission, the engine starts on "under drive" and shifts into "direct drive." Although speeds of 50 mph have been reached, the "over drive" had not been used during the first three weeks of operation.

Other features include the elimination of a cooling system, the ability to start and immediately develop full power without the "warm-up" period common to piston type engines, and the impossibility of stalling the engine.

Most important to the truck operator, however, is the weight-saving feature of the turbine, which has been estimated as high as 2,500 pounds. This weight reduction, combined with the fact that the new Boeing gas turbine occupies only 13 percent of the space normally taken by the conventional 200-hp gasoline or diesel engine, will make possible certain changes in truck design. Kenworth as yet has no new designs on paper, but the compact nature of the turbine will simplify cab-over-engine and other installations in the higher horsepower classification. Improved accessibility is also expected to result.

The Boeing gas turbine is similar to the jet airplane engine in its general design, but the power developed is harnessed by a secondary turbine to turn a shaft rather than being exhausted as jet thrust. Under development for the U. S. Navy Bureau of Ships, it soon will be installed as power unit for propulsion of a boat.

Superior Electrical Impregnating Varnishes Developed

A REPORT, covering several years of research on electrical impregnating varnishes designed to withstand extreme atmospheric and climatic conditions, has been released by the OTS, Department of Commerce.

The research, made for the Signal Corps, has wide commercial implications as electrical motors with durable operating qualifications under adverse temperatures and humidity conditions are becoming increasingly important for use in extreme climates as well as for specialized processes.

Experimental varnishes were developed for the vacuum impregnation of field coils with the following ideal characteristics in mind: non-corrosive, flexible, non-thermoplastic and chemically stable at 150 C; non-brittle at minus 55 C; non-hydroscopic, high wet dielectric strength; soluble in non-corrosive solvent compatible with enameled wire; low viscosity at room temperature; and solidifying primarily by polymerization rather than by oxidation.

The report contains complete details of five clear baking varnishes believed superior to commercial products, and their performance records. Mimeographed copy of the report (PB 98488; Investigation and Research Pertaining to the Development of Process of Impregnation) is $3 from the OTS, Department of Commerce, Washington 25, D.C.

G-E Launches Special Train On Nation Wide Tour

THE GENERAL ELECTRIC CO. is currently exhibiting a 10-car special train described as "the biggest electrical display kit ever built." Called the "More Power to American Special", the quarter-mile long train is filled with exhibits of more than 2,000 of the most modern electric products, systems, and techniques.

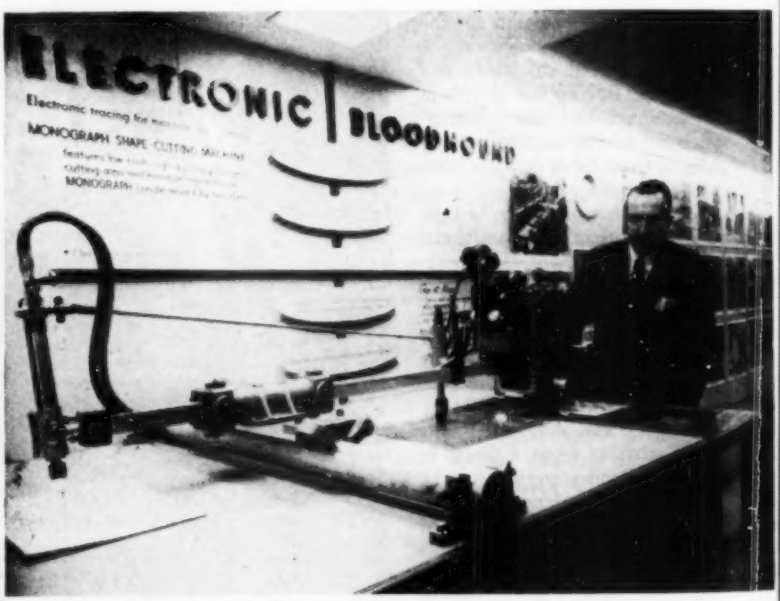
The "Special", launched on the rails by the company's Apparatus Department, started in New York on the first lap of a nation-wide tour. It will visit approximately 150 key industrial centers during 1950 and 1951.

At each stop the train will be inspected by invited representatives of electrical utilities, the manufacturing and transportation industries, the armed services, the federal government, and municipalities.

The train will not be open to the general public during its tour, according to G-E spokesmen. They explained that the exhibits aboard the train have been designed specifically to interest those who produce electric power and those who put it to work in industry and the community.

Exhibits in the "Special" are grouped in 11 major sections: Power Generation, Transmission, and Distribution; Drives and Controls; Materials Handling; Welding; Industrial Heating, Renewal Parts, Industrial Lighting; Components for Industry; Measurements, Civic Improvement; and National Security.

The train is an important phase of the company's "More Power to America" program. Launched immediately following the war, this program is designed to inform industry of the opportunities for improvement through increased electrification. To date about 15 individual MPA programs have been produced and distributed by the company.



THIS EXHIBIT, located in the train's Drives and Controls section, simulates accurate, automatic flame-cutting of metals, with a ballpoint pen (left) substituted for the flame cutter. The detection unit automatically follows a pattern located beneath it and reproduces, through electronic signal processes, the identical pattern on the left.

REPRESENTATIVES of the U. S. Air Force and Navy and experts of the aircraft manufacturing companies see demonstration of a new process for producing strengthened metal developed by Reynolds Metals Company at its Phoenix, Arizona, plant.

Integrally Stiffened Aluminum Skin Seen as Boon to Aircraft Industry

A NEW PROCESS, developed by Reynolds Metals Co., under the sponsorship of Air Material Command, Wright Field, Dayton, Ohio, promises a plentiful production of extruded, stiffened aluminum sheet.

Basically, the process is this: Ribbed sheet is extruded from a press in the form of a large tube, the outside of the tube having a series of integral ribs. This tube is then slit lengthwise and flattened to produce a ribbed sheet. While extremely intricate shapes can be extruded, there are limitations to the process. The development demanded types of extrusions which had never been successfully done before. Maximum die-openings and press capacities at present limit width of sheet that can be produced.

Effect of the die opening size is rather self-evident. However, width of sheet is not limited to diameter of die but rather by the collapsed shape which can be folded in it. For the ribbed sheet, a circular section is most practicable, as it is symmetrical while allowing for a rather large collapsed shape. An S-shape or M-shape is not so practical because the ribs interfere.

Thus, for a die opening of about 10 in., it is practical to extrude a 9-in. diameter shape which can be slit and flattened to produce a ribbed sheet about 27 to 28 in. wide. Assuming the die opening as the limiting factor, a die 20 in. in diameter would permit production of a ribbed sheet approximately 5 ft wide.

The first design worked out as an extrusion involved a 4-in. diameter tube with a $\frac{1}{8}$ in. wall. Most of the development work has consisted in going to thinner walls and larger diameter. At the same time, it was desirable to go from the 61S alloy, easily extruded, to the strongest alloy, 75S (difficult to extrude). After developing several intermediate sizes and learning how to extrude them satisfactorily in 24S, an intermediate alloy, work has now progressed to extruding a 9-in. diameter section with a 0.040-in. wall in 75S alloy.

One of the problems is to control wall thickness uniformly. That is one of the reasons the circular shape was selected to extrude because a die for this is symmetrical and the forces developed in extrusion are exerted uniformly. It is necessary to avoid thick and thin sections as the metal will tend to flow eratically through such a die. Balanced forces in the die help greatly in maintaining uniform wall thickness and tolerance limits.

ASA Announces New Fine-Pitch Gear Standards

THE AMERICAN STANDARDS ASSOCIATION announces the approval of three new American Standards for fine-pitch gears covering straight bevel gears; design for worms and worm gears; and 20-degree involute system for spur and helical gears.

They are part of the gear standardization program developed by a committee organized under the procedure of the American Standards Association, and sponsored by the American Gear Manufacturers Association and the American Society of Mechanical Engineers.

These standards were originally developed by the AGMA during the war years in answer to the great demand for mass production of small gears of high precision. Fine-pitch gears are essential in the manufacture of computing devices, fire control instruments, small automatic mechanisms and other precision instruments.

The technical content of the new American Standard Fine-Pitch Straight Bevel Gears is almost identical with that of the AGMA standard. Modifications are: The clearances have been increased, the tooth thicknesses now correspond to those generated by a crown gear in which the tooth thickness and space width are equal, and the maximum face width is limited to three tenths of the cone distance, or 8/p in., whichever is smaller. The standard covers generated straight bevel gears of 20 diametral pitch and finer, all shaft angles, and with the numbers of teeth equal to or greater than 16/16, 15/17, 14/20, 13/30, for

90-deg shaft angle. The American Standards are being published by the American Society of Mechanical Engineers and when available may be obtained from the ASME, 29 West 39th St., New York 18, N. Y. or from the American Standards Association, 70 East 45th St., New York 17, New York.

What The British Are Doing About Gas Turbines

LONDON—Security prevents the British Admiralty from being very garrulous about what goes on behind the scenes. But, periodically the Admiralty gives a convulsive shudder and brings forth a terse announcement. Here's what the latest such report has to say about gas turbine research:

The Admiralty, being the Government department primarily concerned with developing marine applications of the gas turbine, has undertaken an extensive study of the heavy fuel problem in close collaboration with the National Gas Turbine Establishment. It has been recognized that it will be virtually essential to employ residual grades of fuel for gas turbines at sea. The field of study has been divided into six parts:

(1) Fuel Characteristics: In order to evaluate the problem, a survey is being carried out aimed at giving a comprehensive picture of the nature of the ash forming constituents of crude oils from the various world sources.

Work is also in progress on the problem of developing economical and efficient methods of removing undesirable impurities from residual fuels prior to combustion.

(2) Atomization: An extensive research program is in progress to determine the factors affecting efficient atomization of viscous fuels; rig tests of various types of burner and tests on aircraft type gas turbine engines provide complementary information.

(3) Combustion: Cyclone chambers designed to remove ash from the products of combustion are under active development. More orthodox types of combustion chamber designed primarily for use with residual fuel are also to be tested. Some combustion work on aircraft type gas turbine engines has been carried out.

(4) Heat Transfer: A study of the radiation characteristics of heavy fuel flames and the means of evaluating flame tube, etc., temperatures by heat transfer calculations has been undertaken with particular reference to the elimination of "cold spots" upon which carbon deposits might form.

(5) Blade and Heat Exchanger Fouling: Tests on static blades are being carried out and the composition of deposits and their metallurgical effects are being studied. Aircraft type engines designed for operation of distillate fuel are being run for extended periods on residual fuel to obtain practical data on fouling effects under various conditions of flow. A study of the best means of removing deposits from blading and heat exchangers is also contemplated.

(6) Materials: Work is in hand on the effects of the commoner types of impurities of residual fuel, viz: compounds of sulphur, sodium and vanadium upon the structure and properties of the high temperature materials used in gas turbines. In addition specimen blades from static and engine fouling tests receive examination.

Machine "Imitates" Worker for Time Study Calculations

A NEW COMMERCIAL "TIME STUDY COMPUTER", made by the Potter Instrument Co. of Flushing, Long Island, does a simulated day's work in seconds by imitating both machine and operator actions through electronic tubes. It will be used in the study of frequently changing combinations of automatic machine cycles to calculate the production of each machine.

In a factory employing a number of automatic machines which change their loading and running time cycles frequently as individual job lots are completed, the computation of this allowance has required a large staff of statisticians. This tedious work is now eliminated by the electronic device which completes payroll or production studies much faster and with unbiased accuracy. The computer is operated by one girl who sets dials from work slips. No more skill is required than for an adding machine.

The computer can simulate the operation of as many as ten different machines at one time. Each individual loading and running time which has been determined by usual time study methods is set into the computer, in decimal minutes. A press of a button, and the computer simulates operator and machines for any preset period, at a speed of 1000 elements of time per second. Where times are carried to thousandths of a minute, the time study computer simulates an hour's work in less than sixty seconds.

THE INVENTOR of the Potter "Time Study Computer" instructs a girl operator. The operator takes numbers from work slips, sets them on dials, and presses a button. The computer works out the total loading and running time of the machine it is imitating, as well as operator waiting time and individual machine waiting time.

British Unveil Latest Models at Auto Show

IN AN ATTEMPT to get deeper into the rich U. S. automobile market the still expanding British automobile industry displayed its latest wares recently in New York City. Nearly 100 different motor cars as well as motorcycles, bicycles, trucks and busses were shown, together with accessory equipment.

The outstanding exhibits included the new Rover "Turbo-jet" experimental convertible, and the 400 mph Railton racer, "the fastest car on earth". While these spectacular exhibits drew the crowd, the backbone of the show was the complete line of stock British cars displayed by 22 automobile manufacturers. Prices ranged from $1,000 to $13,000, in styles ranging from the small, economy size to the large luxury models for which the British have long been famous.

The domestic markets for the British and the American motor car manufacturers are at the moment vastly different. The American manufacturer is producing primarily to supply the demand for cars at home in the United States, and whatever he can sell abroad is so much to the good. If his export market fell off completely, he would not be seriously affected. The British manufacturer, on the other hand, is producing primarily for export to overseas markets and largely for the purpose of earning dollars and other foreign exchange upon which Britain must depend for paying for its imports. Sales of British cars in the home market are discouraged by the imposition of a purchase tax that raises the price of a car substantially to the home buyer.

The Turbo-Jet

The Rover experimental turbo-jet convertible was probably the outstanding attraction of the auto show in Grand Central Palace. Fitted into a conventional body, the engine has two combustion chambers fed with air by a centrifugal compressor having a fully shrouded impeller. The fuel, which may be gasoline, kerosene, or diesel oil, is sprayed into these chambers and burns continuously. From these chambers the heated air and combustion products are delivered to the first turbine, which is employed solely to drive the compressor. After leaving this turbine, the air is ducted to the second, or "power" turbine, mechanically independent of the first, which produces power to drive the car through a standard rear-axle differential gear.

World Wide Photos.

THIS NEW ROVER convertible features a "Turbo-Jet" engine developing about 200 hp. An innovation is the machining of each turbine rotor including its blades from a solid disk of nickel alloy, compared to aircraft practice wherein each of the turbine blades is produced separately and later fixed to the rim of the turbine disk. Temperature at the entry to the turbine at times reaches 1,382 F. An automobile-type electric starter, which projects from the rear end of the turbine unit, is used to start the engine. Fuel ignites when the air compressor is turning up 3,000 rpm. Normal idling speed is about 7,000 rpm. No warming up period is necessary, since there are no sliding surfaces to lubricate. A hand brake keeps the auto from inching forward while idling.

Not all the hot gases are effectively absorbed by the turbines, in the experimental model. A heat exchanger, certainly, will be incorporated in the final version, and this will cut the fuel consumption by half or two thirds. A conservative estimate of the consumption of the experimental Rover was from five to seven miles per Imperial gallon of kerosene—a more optimistic one gave it as 12 miles to the gallon, which could be increased to 20 when the heat exchanger is added.

Exhaust gases, after leaving the second turbine, are expelled into the air through louvres in the upper surface of the rear body fairing. The exhaust temperature is not much more than that of a conventional piston engine, now, and when the heat exchanger is incorporated, will be lower than that of present-day automobile power plants. Thus, no damage to the highway will be done, and no danger will be presented to following cars or to pedestrians who cross close behind the car.

The experimental model has been driven faster than 85 mph, at which speed the turbine rotor revolves about 35,000 rpm. Power figures are still restricted, but are around 200 hp. The Rover Company does not expect to put a consumer model turbo-jet on the market for at least 18 months.

UN Wants Us To Share Our Designs With The Russians

A GROUP OF U. S. SCIENTISTS are going to talk over the prospects of sharing our technical knowledge with the Russians. The plan is to set up research laboratories under "world-wide international auspices." This would mean the United Nations.

If you design or invent anything, or any U. S. laboratory perfects some product, you will find the Russians using it the following month—minus benefit of a patent royalty payment.

A national Research Council com-

mittee headed by Maurice Visscher of the University of Minnesota is apparently not concerned with this. To them all science is international.

First proposed by the French in October 1946, the idea of international laboratories has been debated by UNESCO and other UN organizations. Since 1948 a steering committee of experts, including U. S. astronomer Harlow Shapley, has been working on the suggestion. The Russians, having nothing to give up and everything to gain expressed great interest in the "international exchange of research findings."

To military observers, the sharing of our industrial technology with the Russians, is equivalent to furnishing the rope with which they will try to hang us.

British Visual Strain Recorder Displays Multiple Readings During Test

LONDON—The use of the resistance strain-gage is now accepted practice in structural test work, but the recordings have not previously been directly informative. In development testing—as opposed to analytical testing—much of the value of the gaging has consequently been lost. The advantage of obtaining a visual record while a test is actually in progress has always been realized, but suitable equipment has not been available.

With the object of repairing this deficiency, the Research Department of Airspeed Ltd., at Christchurch, Hampshire, England, started work some time ago on the development of apparatus which would combine automatic and visual recording while using the "null" method. The Airspeed Polygraph Recorder, as the equipment is named, has now been in successful use for some time, both in Airspeed's own test house and, more recently, at the Royal Aircraft Establishment, Farnborough.

The Polygraph strain-gage recorder automatically accepts and displays the readings from any number of gage points in rapid succession. The results are seen in the form of load-strain graphs, each 5 in. by 3 in., arranged in columns on a display board. A stylus, mounted in a carriage which travels horizontally along the board or easel is connected, via an electronic circuit, to a potentiometer, which balances each of the Wheatstone bridge circuits in turn. The behaviour of every gage point can thus be individually studied as a test progresses.

As the number of gages required for a test may vary considerably, the Recorder has been made in 100-way units, and additional units can be added, both to the easel and at the control box, to deal with any number of gages. It has been found, as a result of practical experience, that a production version of the machine could be more compact and its recording speed considerably increased.

The applications of the Polygraph Recorder are wide. Not only is the strain at any gage point immediately visible, but the slope of the load/strain curve can be watched and any irregularities immediately detected. The apparatus is thus of great value to the designer, who can follow visually the behaviour of a test specimen. For development testing this is a most valuable feature, as it is always possible to arrest a test for minor reinforcements before final collapse at or above the appropriate strength requirement. Thus, time and money can be saved and the maximum amount of information obtained from a single test structure.

Free Piston Air Compressor Has Possible Navy Use

THIS JUNKERS FREE PISTON DIESEL AIR COMPRESSOR was used aboard German destroyers and submarines during World War II as a source of high pressure air. It was tested and sectionalized by the U. S. Naval Engineering Experiment Station, Annapolis, Maryland and is now on display in the Marine Engineering Department of the U. S. Naval Academy. The free piston type compressor differs radically from the conventional type due to the absence of crankshaft and flywheel. The motion of the pistons is controlled by the gas and inertia forces. The unit is light and efficient and has a high output for its weight and volume. Because of these features and its inherent balance, it offers promise as an air compressor in our submarines.

Air Force Gets Simulator

AN ANALOG COMPUTER, or simulator for the analysis of transient heat flow has been constructed for the U. S. Air Force by Reed Research, Inc., Washington, D. C. It will be used in the solution of problems encountered in guided missiles, rockets, gas turbines, etc. The machine, costing approximately $150,000, is capable of 200,000 calculations a second.

The machine employs the analogy between certain properties of an electric circuit and the thermal characteristics of matter. Voltage is made analoguous to temperature and current

to rate of heat transfer. Electrical resistance and capacity are analoguous to heat transfer and heat storage factors respectively.

Provision is made for the variation of input voltages and currents, and of certain resistors in the circuit either as a function of time or as a function of a voltage in the circuit.

Output data are in graphical form. Twenty-four voltages and four currents appear as a function of time on a special recorder designed for the purpose. Overall accuracy of measurement and recording is ± 1 percent.

The unique input arrangement allows the introduction of non-linear transfer functions. This consists of aluminum templates shaped like the graphs of the required functions (empirical or analytical). Template followers transform the ordinates of the curves to values of resistance, voltage, and current by means of suitable electronic devices. The parameters representing thermal conductivity and heat storage are adjustable over a large range; one million to one for conductance and 20,000 to one for storage. There are three times bases: 10 minutes, one hour, and 8 hours.

National Science Bill Becomes Law

AFTER SEVERAL YEARS OF STRUGGLE, change and compromise, the U. S. has created a National Science Foundation.

A previous bill was passed by the 80th Congress, but was pocket-vetoed by President Truman. He objected to the administrative set-up under the bill. This defect is remedied in the present bill which provides for Presidential appointment of the Director of the Foundation from among those recommended by the 24-man Board. The appointment would then be confirmed by the Senate. Suggestions to the President of names of persons qualified to serve on the board are invited from learned societies, universities and scientists.

The most controversial issue blocking passage of the bill concerned the House-approved provision requiring that Foundation employees and researchers have FBI security clearance. The compromise bill permits the AEC and the National Defense establishment to apply their own security regulations to any researchers in the Foundation handling information restricted by these agencies. The Foundation would set up its own security safeguards. Only employees who handle restricted information would be required to have an FBI check. The actual clearance would come from the Foundation itself after an examination of FBI reports. A previous form of the bill required the FBI to judge the fitness of an individual.

The final bill sets up a 24-member National Science Board and a $15,000 a year director, all appointed by the President. This removes the chief objection of the President to previous bills which allowed the Science Board to choose its own director. As the bill now stands, the Board may recommend a qualified director to the President.

While the first year's appropriation would total only $500,000, the recently passed bill provides for a ceiling of as much as $15-million a year thereafter. The Foundation is concerned especially with basic research.

"Erector Set" Bridges Studied by Dept. Commerce

PRESTRESSING PRINCIPLES have been applied in the design of a prefabricated portable bridge that can be stockpiled for emergency use. These spans consist of precast concrete "U" sections 10 feet long and 2 feet wide. Sections are placed end to end for a maximum span length of 50 ft, and are made into one continous beam by threading cables through the members and stressing the cables sufficiently to take the necessary load.

The general plan would be to stockpile in each state sufficient material to install a number of spans for emergency use. These temporary spans would of course be taken down and re-stockpiled when the damaged bridge was rebuilt.

The ten-foot beam sections can be assembled on shore and the beam set in place on its supports by a crane, without falsework. This operation is repeated until a sufficient number of beams are in place to give the desired width of roadway. The outside beams are then placed and cables are threaded transversely. The sections are pulled together by stressing the transverse cables the necessary amount to make the span act as a unit.

An important feature of the design is the fact that the sections are comparatively light and easily portable. A 10-foot section weighs slightly over one ton, and a 50-foot section consisting of 5 units weighs approximately 6 tons. Variable lengths and widths can be obtained by stockpiling different lengths of concrete sections and different lengths of cable. The span is designed to be manufactured at a concrete pipe plant, using steel forms that would be supplied by the highway department.

The bridge design was developed—with the help of the Committee on Bridges and Structures of the American Association of State Highway Officials — by the Bureau of Public Roads, U. S. Department of Commerce. Raymond Archibald, bridge engineer for BPR, is chairman of the AASHO committee. John A. Roeb-

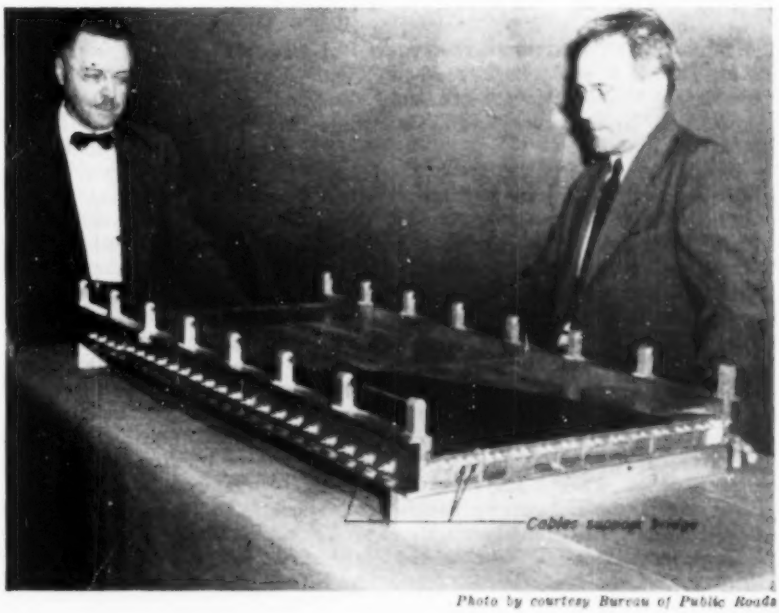


Photo by courtesy Bureau of Public Roads

ling's Sons Co., Trenton, N. J., has collaborated in the design of the prestressing cables and fastenings. BPR plans to build a test prototype at its laboratory proving ground in Virginia, across the river from Washington.

Live Fuses Take a Jolting

VISITORS AND GUESTS at the March 23 dedication of the Naval Ordnance Laboratory's new Environmental Test Building witnessed the "last word" in safety testing of equipment.

They saw a new rough-handling machine, designed at NOL, which is capable of shocking fuzes in nearly every conceivable direction. The machine replaces older "jolt and jumble" equipment. It can produce 1,024 shocks per cycle in 962 different direction. The cycle requires about 17 minutes to complete.

The fuse to be tested is fastened to a rotating striker-head. This head is permanently attached to a lever which raises it up and then drops it onto a cushioned anvil. This is repeated in 962 directions, thus shocking the live fuze at almost every angle.

With this new machine NOL will be able to prescribe designs for fuses pected to assist in setting up standards for safety testing of fuses for the National Defense Establishment.

Transparent Bearing Aids Lubricators Study

A TRANSPARENT PLASTIC BEARING enables Texas Co. engineers to see and photograph the behavior of oils and greases in bearings under different loads and speeds.

Bright red dye is mixed with the lubricant so that the lines of flow can be followed. Sensitive scales on the test machine measure the friction drag. Operating temperatures are measured electrically by means of thermocouples and a potentiometer. Although a plain journal bearing is under test at present, the machine can be adapted to also study ball and roller bearings.

The special test machine and Lucite bearing were designed and built at the Texaco research laboratories at Beacon, New York. The work is being done at the Engineering Experiment Station of the Pennsylvania State College, in collaboration with the staff there.

Photo by USAF Air Material Command

THE GALLON-SIZE POLYETHYLENE CONTAINER being ground under heel here was designed by Packaging Branch of Air Material Command's Materials Laboratory to eliminate the hazards involved in transporting acids in glass bottles. For surface shipment the glass containers are safe enough, but air transportation is more strenuous.

Special Problems of Air Transportation Are Studied

THE PROBLEMS of transporting dangerous-to-ship packages by air is being studied by the Packaging Branch of the Materials Laboratory at Wright-Patterson Air Force Base, Dayton, Ohio.

A new test chamber installed recently at the laboratory simulates flight conditions posed by temperature, altitude and vibration. The chamber, which resembles a large walk-in vault, can be changed from sea level to 50,000 ft altitude conditions in three minutes and can have its temperature lowered 100 F in that same period. The operating temperature range of the test chamber extends from 165 F above to 65 F below zero. An especially designed vibration table installed in the floor of the chamber carries loads up to 1,000 pounds and has cycles of 600 to 3,600 vibrations a minute. The Wright Field chamber is the first to combine all three elements of temperature, altitude and vibration.

Tests conducted by the Air Material Command's Packaging Branch have resulted in the development of distinctive containers for dangerous items such as acetone, sulfuric and nitric acid, varnishes, cleaning fluids, ethers, ammunition, etc.

Outer packages are usually made of metal, fiber, wood, while cushioning may be cellulose fiber, sponge rubber, fiber glass or curled hair and latex. Insulation is provided by any material that would prevent the transfer of heat and cold to the contents of the package, such as cork and asbestos. An air space often provides the most suitable insulation.

As an example of containers developed by the AMC's Packaging Branch, hydroflouric acid is transported by air in a pliable bottle of polyethylene. A specially designed container of the same material is used for battery electrolyte for spare aircraft batteries. Thermometers and other mercury-filled items are packaged in outer containers of metal. The main problems of air transport are presented by extremes of temperature and pressure, which, of course, vary greatly with altitude. Pliable bottles of polyethylene solve many of these problems.

All Patents on Welding Classified at Ohio State

DEPARTMENT OF WELDING ENGINEERING at Ohio State University has announced completion of a new Patent Classification Index in the A. F. Davis Welding Library, designed to make information on more than 12,000 U. S. patents on welding more easily available to industry and educational institutions. The index covers not only the fundamental patents on welding processes and equipment, but also the important field of industrial applications of welding processes.

Patents are divided into nineteen groups, each patent being classified or indexed in several different ways—by process, material, product, use, inventor's name, date of issue, etc., on a single keysort card.

The great advantage of the Patent Index is the speed with which relevant patent numbers can be obtained. Most searches can be accomplished in from 3 to 20 minutes, and their value is limited only to the completeness of the patent file.

Use of the classification system is offered to industrial organizations, individuals and educational institutions. Services are free of charge to those who use the index system in person, but modest charges to defray clerical expense will be made for inquiries handled by mail.

Gas Turbine Locomotive Is Under Construction

AN EXPERIMENTAL 4,000-HP GAS TURBINE LOCOMOTIVE is now under construction by Westinghouse Electric Corporation.

The locomotive will use various types of liquid fuels ranging from light diesel oils to the heavier Bunker C oils. It will generate electricity for the driving power in the same way that diesel engines are now used, but the gas turbine locomotive will have approximately two-thirds of the weight and one-half the length of the diesel locomotive.

The gas turbine and the diesel of equal plant capacity are strictly on a par except that the gas turbine can haul one more car because of lower locomotive weight. Any major advantages achieved by either will stem from the operating economies of the prime mover. Other experimental turbines for locomotives are in various stages of development.

News Briefs

A DIESEL-POWERED RACER will compete this year in Indianapolis Memorial Day Speedway classic. This is the first time since 1931, when a diesel-powered racer finished 13th in the 500 mile race without making a stop.

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THE NACA recently celebrated its 35th anniversary at a recent meeting in Washington. Capt. Halden C. Richardson, USN, NACA's first secretary and John F. Victory, first NACA employee, were among those present.

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FORMULA TAMPERING RUINS many good adhesives and causes failure, according to officials of Paisley Products, Inc., of Chicago. They urge users to follow the rules laid down by the manufacturer when diluting industrial adhesives.

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A FIVE MAN JURY has been chosen by the Resistance Welder Manufacturers Association to judge the various papers in the RWMA prize contest on Resistance Welding Design, Application and Research. Prizes totalling $2,250.00 will be distributed.

•

AN ENGLISH TRACTOR which runs on kerosene is designed especially for use in the Middle East, where low grade lamp oil is the only available fuel. Harry Fergusen Ltd., Coventry, is the maker.

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TWELVE EDUCATIONAL INSTITUTIONS have been offered Eastman Kodak Company fellowships for advanced studies in chemistry, physics and chemical engineering. Tennessee Eastman Corporation, a Kodak subsidiary, will also sponsor a limited additional number of fellowships at educational institutions in the Southern states.

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THE 32ND INTERNATIONAL AUTOMOBILE SHOW—one of Italy's biggest commercial exhibitions—was held May 4-14 in Turin. Seven nations were represented—Belgium, France, Germany, Great Britain, Italy, Switzerland, and the U. S.

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GROWING PAINS have got the rocket engine industry in their grip. According to Harry B. Horne, Jr., of the American Rocket Society, rocket data is being applied so fast to the development of new engines that the scientists engaged in fundamental research are far lagging behind.

MOTOR AND GENERATOR BRUSHES made of graphite wear out rapidly in high flying aircraft because there is no moisture in the air. A new process, developed at G. E. supplies the needed water vapor and increases brush life many thousands of times.

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THE DEADLINE FOR RETURNING ENGINEERING SURVEYS to the U. S. Office of Naval Research has been delayed to July 15. Surveys were sent to 115,000 members of 18 engineering societies in an effort to build up a file of key engineers who can be called in on a full or part time basis by the National Military establishment.

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SUCCESSFUL OPERATION in its first phase of a new type of atom smasher, which is ultimately expected to produce X-rays of 300,000,000 volts, was announced by the General Electric Co.

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PROCESSING INDUSTRIES IN THE UNITED STATES will continue to grow at the rate of about two and a half billion dollars per year during the 1950's, according to the American Society of Mechanical Engineers.

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AN ELECTRONIC DEVICE capable of the generation of pulses of energy existing for only 1,000th of 1,000,000th of a second (milli-microsecond) has been developed by the Signal Corps Engineering Laboratories, Fort Monmouth, N. J. The device is expected to provide the basis for many advancements in military electronic equipment, particularly in the field of radio communications.

•

AN INVENTION THAT USES LIQUID AMMONIA as a fuel for automobiles has just been patented by Bert Mudde, a Dutchman of Leidschendam. A small tank with a 3-litre content is attached to the engine, and to this tank an electrolysis apparatus has been fixed. The tank is filled with a concentrated and very volatile solution of ammonia, which is turned into ammonia gas, hydrogen and oxygen and directed to the cylinders.

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A PHOTOGRAPHIC FILM that will work like a charm in arctic cold or tropical heat has been developed by scientists at Armour Research Foundation of Illinois Institute of Technology.

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THE FCC may be expected to announce its decision on color TV sometime during the summer. The industry is anxiously awaiting a decision that could either make or break it.

STEEL MILL REPORTS DOW CORNING SILICONE (CLASS H) INSULATION GIVES 30 TIMES THE LIFE OF CLASS B ON CRANE MOTOR

$79 Saves $3634
(+maintenance labor +lost production)
on 1 Motor Rewound
with DC Silicone
(Class H) Insulation!
Further proof of the fact that Dow Corning Silicones pay for themselves many times over in reduced maintenance costs alone!

Motor rewound by National Electric Coil Company

DON'T LET DOWN TIME EAT UP YOUR PROFIT MARGIN!

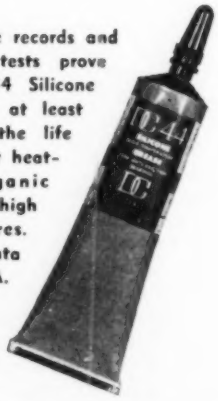
Cost conscious maintenance men throughout industry now specify Class H Insulation made with Dow Corning Silicones. It keeps hard working, critical motors on the job. Here's a typical example from the steel industry. A cupola crane hoist motor insulated with the best Class B materials failed 22 times between June 1942 and July 1945. Average life was only 50 days; rewind costs alone amounted to $3,634.

Then National Electric Coil Company of Columbus, Ohio, rewound the motor with Class H (DC Silicone bonded and impregnated) Insulation at an extra cost of only $79. That motor, still in good condition after 613 days on the hoist, was transferred to the trolley bridge. It's still in service after a total of 1521 days.

You can't afford to postpone that kind of production economy. Figure the cost of down time in lost production, man hours of labor and maintenance costs. Consider the cost of stand-by motors and spare motors in inventory.

DC 44 SILICONE GREASE CUTS MAINTENANCE AND DOWN TIME DUE TO BEARING FAILURE

Performance records and laboratory tests prove that DC 44 Silicone Grease has at least 10 times the life of the most heat-stable organic greases at high temperatures. Write for data sheet L-18A.



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Dow Corning Silicones Mean Business!

Call our nearest branch office today. Our men will be glad to help you multiply the life of your hardest working motors with DC Silicone (Class H) Insulation. If you need more evidence, write Dept. L-18.

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FIRST IN SILICONES

Finishes Available in Copper Alloy Sheet and Strip

Acid Dipped—Dry Rolled Finish. The finish obtained by cold dry rolling on polished rolls of material previously bichromate dipped or bright dipped, giving a burnished appearance and retaining the color obtained by dipping.

Bichromate (Dichromate) Dipped Finish. The finish obtained by immersion in a solution of a bichromate and sulfuric acid, resulting in substantially complete removal of scale and oxide and giving a color approaching the true color of the metal.

Bright Dipped Finish. The finish obtained by final immersion in suitable oxidizing acid solutions resulting in a complete removal of scale and oxide and giving the true color or approximately the true color of the metal.

Buffed Surface. See Polished Surface.

Cold Rolled Finish. The finish obtained by cold rolling plain pickled strip with a lubricant, resulting in a relatively smooth appearance. In the case of sheet, cold rolling may be done without any lubricant, the finish then being similar to that described under Dry Rolled Finish.

Dichromate Dipped Finish. See Bichromate Dipped Finish.

Drawn Finish. The finish obtained on tube, wire, and drawn rod, bar and strip by drawing through a die, resulting in a relatively smooth and bright appearance.

Dry Rolled Finish. (Bright Rolled Finish). The finish obtained by cold rolling on polished rolls without the use of any coolant or metal lubricant, of material previously plain pickled, giving a burnished appearance.

Extruded Finish. The finish obtained on tube, wire, rod and bar by hot extrusion through a die, resulting in a slightly oxidized and dull appearance.

Hot Rolled Finish. (Left Black). The finish obtained by rolling metal while hot, resulting in a dark oxidized and relatively rough surface.
Note: This material may subsequently be pickled, bichromate dipped, or bright dipped, but the relatively rough surface remains.

Kerosene Rolled Finish. (Also Soap Rolled and Soluble-oil Rolled). The finish obtained by cold rolling with kerosene, soap or soluble-oil as a lubricant, giving a semi-burnished appearance.

Plain Pickled Finish. The finish obtained by immersion in a sulfuric acid solution. This effectively removes most heavy scale and oxides on yellow brasses, but less effectively on other alloys and will not remove any thin surface films of deposited copper. The color is, therefore, usually duller than that of bright dipped or bichromate dipped material.

Polished Surface. (Buffed Surface). The finish obtained by buffing with rouge or similar fine abrasive, resulting in a high gloss or polish. This may be applied in one operation or two, commonly known as cutting and coloring operations.

Red Dip Finish. This term is not recommended. Use instead the term "Bichromate Dipped Finish".

Satin Finish. See Scratch Brushed Finish.

Scratch Brushed Finish. (Satin Finish). The finish obtained by mechanically brushing the surface with wire bristle brushes or by buffing with greaseless compound.

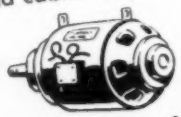
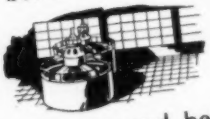
Soap Rolled Finish. See Kerosene Rolled Finish.

Soda Dip Finish. This term is not recommended. Use instead the term "Bichromate Dipped Finish".

Soluble-Oil Rolled Finish. See Kerosene Rolled Finish.

Courtesy Copper and Brass Research Association

The right wire for the right job...

Technological advances in many industries constantly require new developments and new applications of wire and cable. A space-saving wire design has made possible smaller, more compact  motors. A new and better form of heat resistance in turn prevents failure in generators.  Again, if a sharp turn can be given a wire, a new and better clock may be possible. New abrasion characteristics may mean milady's iron won't fail. A city's safety is made more certain because a solenoid sets new records in performance. As simple a thing as better shielding in a wiring harness can be the secret of clearer radio and television reception. Auto-Lite Engineers, drawing on their many years of automotive experience, can answer such problems. For more complete information on the "right wire for the right job" write on your company letterhead to

THE ELECTRIC AUTO-LITE COMPANY

Wire and Cable Division

Port Huron, Michigan • **Hazleton, Pennsylvania**

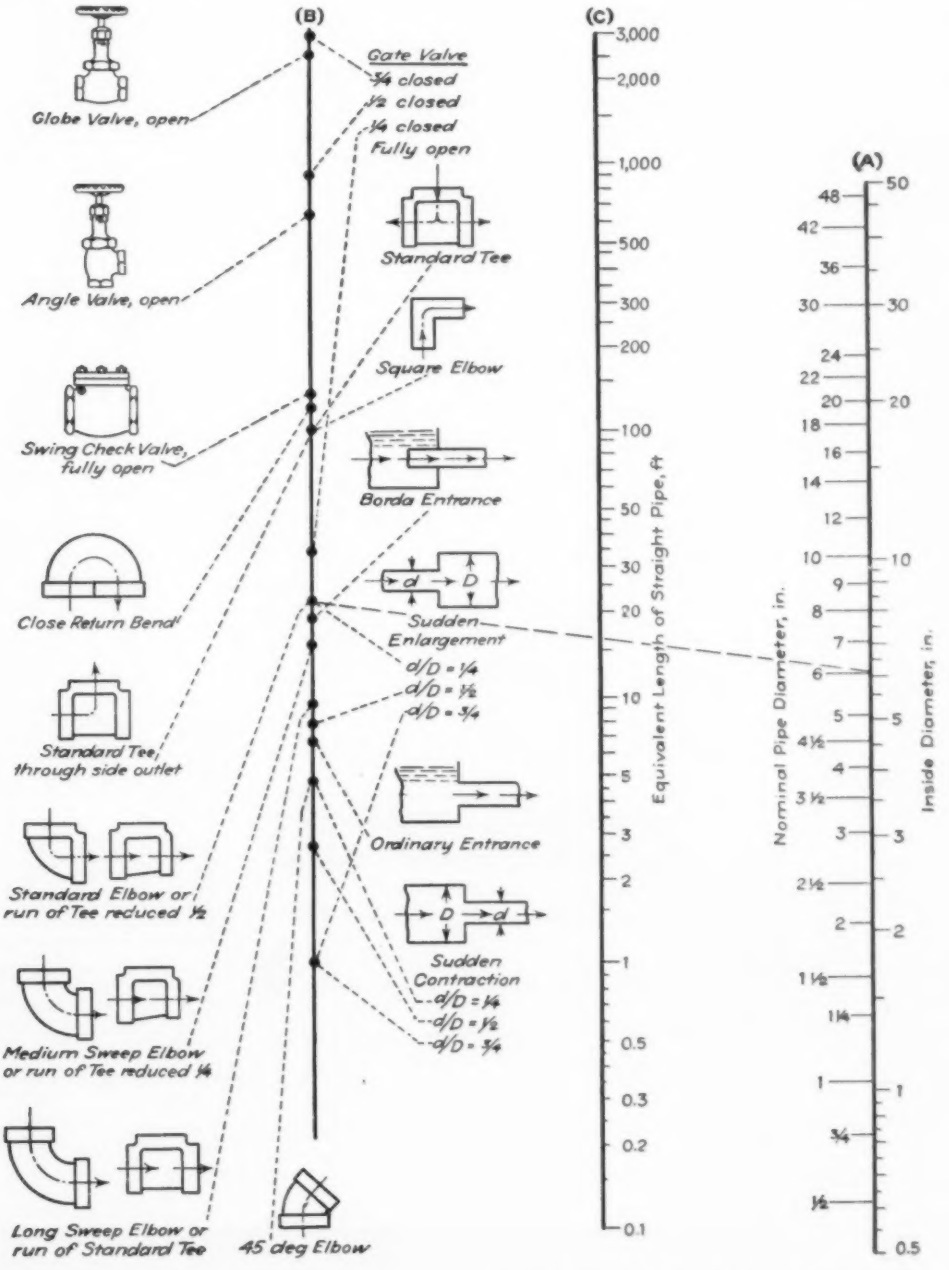
AUTO-LITE

die castings
plastics
wire and cable
industrial
thermometers

Fluid Resistance of Valves and Fittings

THE SIMPLEST WAY to account for the resistance offered to flow by valves and fittings is to add to the existing length of pipe an additional length which has the identical resistance of the valve or fitting. The graph gives the additional or equivalent length of pipe which is added, for each particular resistance, to the length of the piping system. For practical purposes, the equivalent length given is independent of the kind of fluid or the velocity of flow. In using this chart, the smaller diameter of the nominal pipe size shall be used for sudden enlargements or contractions.

EXAMPLE: Find the equivalent length of pipe for the resistance of a 6 in. Standard Elbow. Draw a line from the Nominal Pipe Diameter (Scale *A*) to the Standard Elbow (Scale *B*). The intersection of this line on Scale *C* gives the Equivalent Length of approximately 16 feet.



Material courtesy of Crane Company, Chicago, Ill.

See A Cost-Cutting Shape Here?

If you machine stainless steel bars or wire for parts of your products, there's a good chance you can cut costs and save time with special shapes of Armco Stainless Steels.

Various special shapes similar to those indicated on this page have given many manufacturers three big advantages:

1. **Less steel lost in machining**
2. **Fewer fabrication operations**
3. **Greater production**

In most cases only finish-machining operations are necessary for precision parts when you use special shapes of Armco Stainless Steel bars or wire. This cuts shop time and eliminates many preliminary operations that may be necessary with conventional shapes.

Whether your problem is one of engineering or manufacturing, Armco consultants will be glad to supply you with information about stainless steel bar or wire shapes designed to your exact specifications.

For complete information just fill in the coupon and mail it today.

ARMCO STEEL CORPORATION

4940 Curtis St., Middletown, O. • Plants and Sales Offices from Coast to Coast • The Armco International Corporation, World-Wide

here's our problem

Armco Steel Corporation
4940 Curtis St., Middletown, Ohio

Can you supply a bar shape like this?

Size_____

Purpose_____

Name_____ **Company**_____

Street_____

City_____ **Zone**_____ **State**_____

Discharge of Water to Atmosphere

THIS NOMOGRAM can be used to calculate either the flow of water through an orifice or the flow through a section of straight pipe. It is based on the equations:

$$Q = 450\, C_d\, A\sqrt{2gh} \qquad \text{(orifice equation)}$$

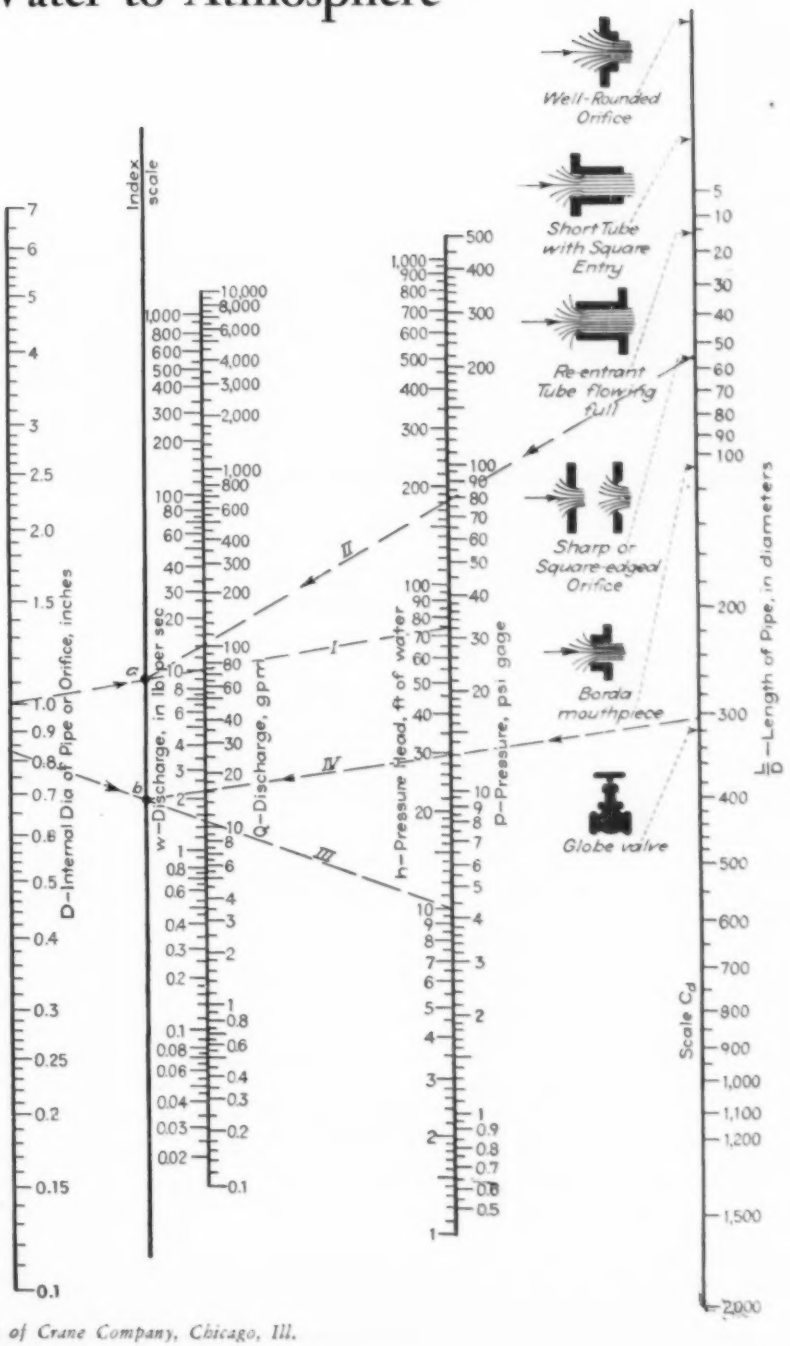
$$q = \frac{A\sqrt{2gh}}{\sqrt{1.5 + f(L/D)}} \qquad \text{(pipe equation where } f = 0.018\text{)}$$

where:

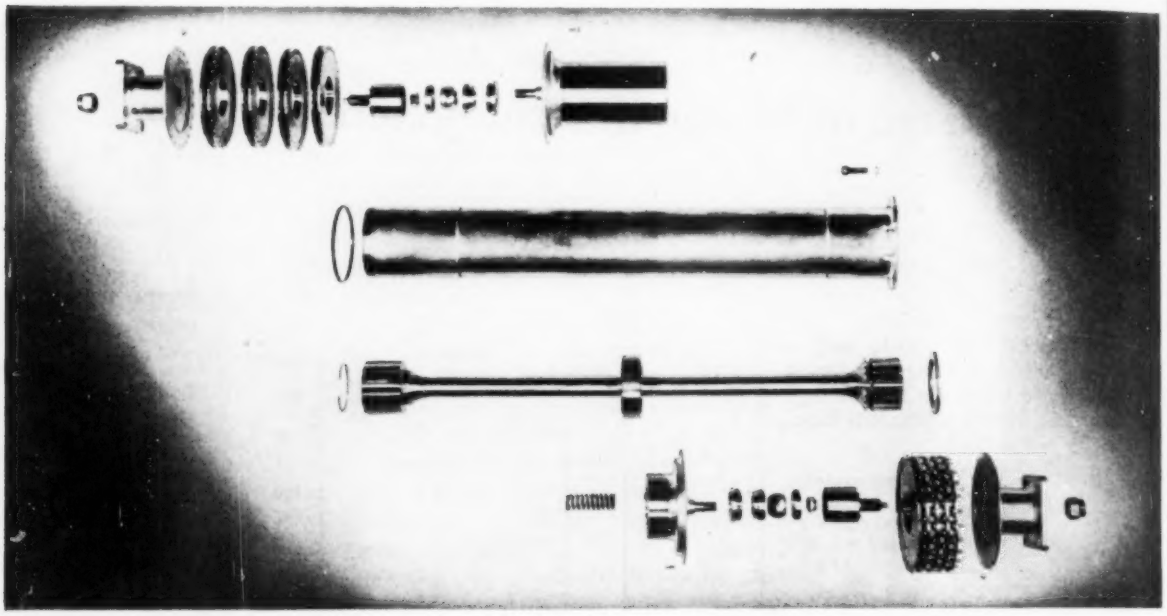
Q = discharge, gal per min
C_d = discharge coefficient
A = orifice area, sq ft
g = gravitational constant (32.2 ft per sec^2)
h = static head, ft
q = discharge, cu ft per sec
f = friction factor
L = pipe length, ft
D = inside pipe dia, ft
d = inside dia, inches

EXAMPLE 1: Find rate of water flow through 1 in. sharp-edged orifice with a static pressure head of 75 feet. Draw line I from 1 in. on D scale to 75 ft on h scale. Line II is drawn from intersection of line I and index scale (point a) to sharp-edged orifice point on C_d scale. Flow is approximately 104 gallons per min on Q scale. (Or 14.2 pounds per sec on the W scale.)

EXAMPLE 2: How much water will be discharged through 21 ft of $\frac{3}{4}$ in. standard pipe with pressure head of 10 ft? The inside diameter of $\frac{3}{4}$ in. standard pipe is $d = 0.824$ inches. Draw line III from 0.824 on the D scale to 10 ft on the h scale. The intersection of line III and the index scale is point b. Line IV is drawn through point b and $L/D = \frac{21 \times 12}{0.824} = 306$. The flow is found to be 16 gal per minute.



Material courtesy of Crane Company, Chicago, Ill.



THIS EXPLODED ILLUSTRATION of one model of the new universal drive shaft shows completely and partially disassembled views of the diaphragm joints.

The long quill shaft serves to absorb and minimize any torsional oscillations introduced by the engine or driving members. Ball joints permit any shaft misalignments to be taken up by the diaphragms. One of the problems inherent to the ordinary universal or Hooke's joint is the introduction of torsional accelerations by the joint. Since the new steel joint is a constant-velocity unit, this problem is eliminated.

Steel Accordion Makes Flexible Coupling In 300 Hp, 9,000 Rpm Shaft Assembly

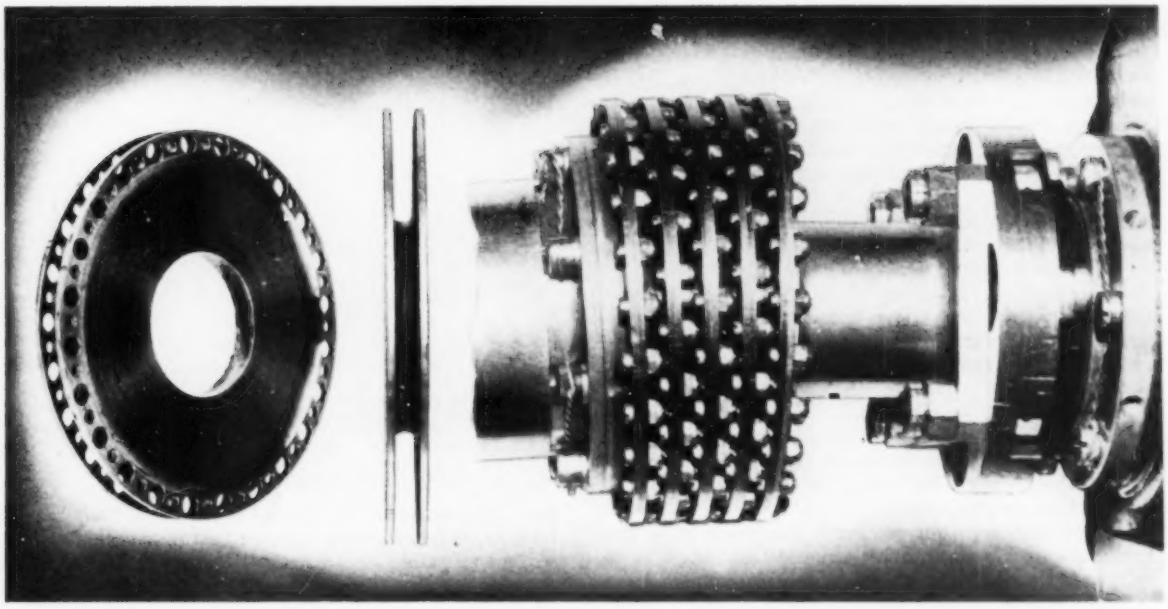
This universal drive shaft is a high-speed flexible coupling, one design of which has been operated continuously at loads up to 300 hp, speeds up to 9,000 rpm, angular misalignment up to 4 deg, and variations in axial length up to 1¼ in. The shaft consists basically of two constant-velocity flexible joints splined to each end of a long quill shaft. This new unit is light and free from backlash. The load-carrying members require no lubrication and no heat is generated. Due to the symmetry of the design, any balancing problems are minimized.

Although initially designed as a heavy-duty drive for a remotely-driven, 300 hp gear box, the shaft, in a considerably lighter version, lends itself to driving remotely-mounted generators, pumps, superchargers, etc. Adoptions are also being worked on for flexible joints in heliocopter drive shafts at more than 1000 hp ratings. At present, the shaft has been run for more than 350 hours at loads between 180 and 225 hp, at deflections up to 4 deg, and speeds ranging from 6,600 to 9,000 rpm. Approximately 120 hours of the run were conducted with one end of the shaft vibrated radially at a double amplitude of 0.03 in. at frequencies ranging from 7,700 to 10,500 cpm. In additional tests now underway, a diaphragm joint has been running deflected the equivalent of 10 deg at speeds of 8,000 to 11,000 rpm. The joint has now been operating for some 1,500 hours without any servicing and is still running as of this writing. Research work is continuing and applications are expected in power transmission phases of the aircraft, automotive, agriculture and process industries.

Heart of the new coupling is a series of eight steel diaphragms, each having a hyperbolic wall section whose thickness tapers to less than ten thousandths of an inch. These wafer-thin disks provide the flexibilty necessary to permit misalignment up to 3½ deg, yet are rugged enough to absorb power surges, peak speeds and maximum loads.

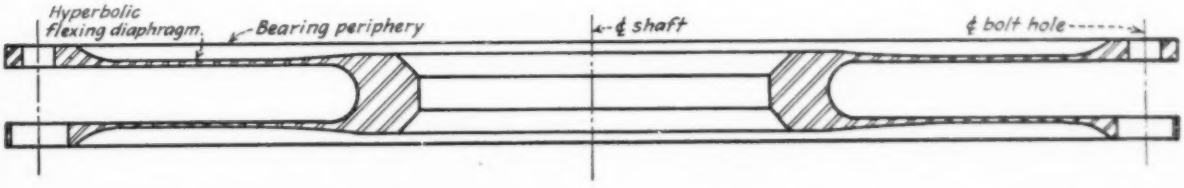
MATERIALS AND PARTS

SPECIFIED BY PRODUCT ENGINEERS



(LEFT) Each flexible joint is made up of four of these double-flanged members. Angular displacement is obtained by resilient diaphragm flexure. There is no energy loss due to friction in the torque transmitting members, and no lubrication is required. Cross-section view of a single flanged member is shown below.

(RIGHT) Right-hand end of the shaft shown in exploded view on the opposite page. Note compensation for misalignment. The load carrying members of a joint rated at 300 hp weigh only 1½ lb assembled and are only 4¼ in. in diameter. Assembly shown was designed for aircraft engine auxiliary drive takeoff.



The design of the individual diaphragms was dictated by the following considerations. Since the misalignment was taken by the flexing of the steel member, it was imperative that the combination of torsional stresses introduced by the load, and the bending stresses brought on by flexure be held within allowable limits in every part of the working member. Moreover, to avoid the sharply curtailed fatigue life brought on by local stress concentrations, the combined bending and torsional stresses had to be distributed evenly throughout the working cross section of the diaphragm. When a disk of constant web thickness was subjected to a bending load equivalent to 1½ deg joint misalignment, examination of the stress coat pattern revealed that the stress was not distributed evenly but was confined to a narrow area around the hub. Thus it was made apparent that to obtain a more uniform distribution of the bending stress, the thickness of the bending member had to decrease with the increase in distance from the center. In addition, a diaphragm profile defined by the relationship

$$t = K / R^2$$

t = web thickness
R = radial distance to any point of thickness t on web
K = constant defined by desired torque and stress loads

will provide for uniform torsional shear stress across the entire working cross section. When the diaphragm, illustrated in cross sectional view above, was built and subjected to the specified bending and torque loads, the stress pattern was found to be uniformly distributed as desired. A round valley minimizes stress concentration between diaphrams.

Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.

For more information circle No. 1 on Reader Service Card

CONTINUED ON PAGE 162

100 Va Inverter Holds Frequency to 0.1 Percent

This inverter transforms 28 v dc to 400 (± 0.1 percent) cycles per sec, 115 v (± 1 percent) single phase and/or 115 v (± 3 percent) three phase. Inverter features are exceptional frequency and voltage stability over extreme ranges of temperature, altitude, load and input ranges; and absence of moving parts. Output is 100 va, power factor 0.4 to 0.8 lag, weight 19 lb, volume 620 cu in. The transformers, reactors, etc., are impregnated to withstand abnormal environmental conditions; all relays, potentiometers, etc., are hermetically sealed. Condensers, resistors, vacuum tubes, and standard parts are JAN approved wherever possible.

The new inverter consists fundamentally of four sections: (1) Frequency Generator, (2) Single Phase Inverter, (3) Voltage Regulator, and (4) Phase Adapter.

The frequency generator is composed of a precisely tuned, miniature tuning fork within a hermetically sealed, constant temperature envelope. This fork, incorporated in an electronic circuit, furnishes the power to drive the inverter thyratrons. The frequency is stabilized at 1/10 of 1 percent.

The single phase inverter section, comprises a transformer, and a specially designed commutating condenser, in conjunction with two thyratron tubes, arranged in a parallel type inverter circuit.

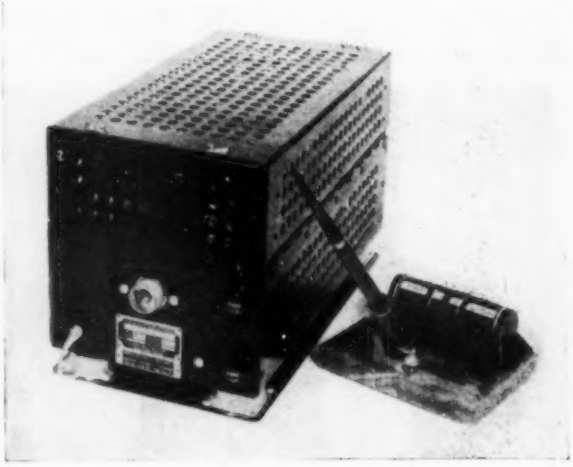
The voltage regulator section is composed of a single bridge circuit which controls a saturable reactor. This permits recovery of output voltage within ½ second.

The phase adapter section is composed of a variable inductive leg and a variable capacitive leg. By electronic means, the sensing and control of the phase angle and voltage of each phantom leg is maintained.

The inverter incorporates an automatic "kick-out" and "re-cycling" system as well as a fused input line. During excessive overloads, the kick-out will automatically stop the inverter, before blowing the fuse. After a period of three sec, the re-cycling device re-starts the inverter. This system restores power without manually re-starting or replacing fuses, after a short or other excessive load appears across the output.

Initial warm-up time is 25 sec. Materials and workmanship are in accordance with AN-1-106 and AN-E-19.

Varo Mfg. Co., Garland, Texas



THE FOUR COMPONENT PARTS are mounted and enclosed in an aluminum housing. All parts and assemblies are accessible. Electrical connections are made by an AN connector plug.

For more information circle No. 2 on Reader Service Card

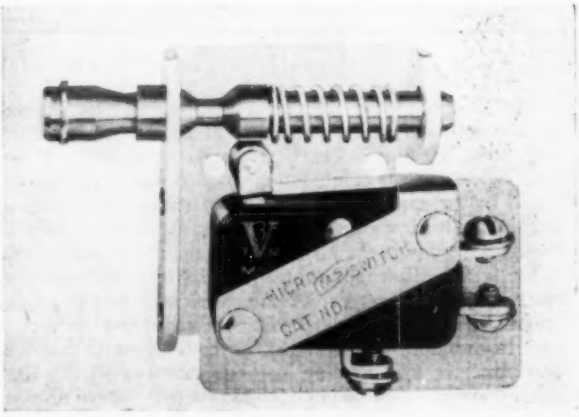
Automatic Switch Allows Safe Testing

This door switch assembly automatically cuts off the power circuit when a high frequency cabinet door is opened, thereby safe-guarding personnel who have occasion to open cabinet doors on high frequency radio, radar, X-ray, television, induction heating and other electronic control equipment.

The unit consists of a combination mounting bracket, rod actuator, and a roller lever operated, snap-action precision switch, operated by opening and closing the cabinet door. Personnel can close the circuit for checking by manually moving the rod actuator to the maintained contact position. The actuator automatically returns to the normal position when the door is closed. The next door opening breaks the circuit.

This interlock switch assembly has single-pole, double-throw circuit arrangement, with electrical rating of 10 amp 110-220 v, a-c; and 10 amp 28 v, d-c, non-inductive load, 6 amp 28 v, d-c, inductive rating. The unit measures $1\frac{7}{8}$ in. long, by $\frac{33}{64}$ in. deep, by $1\frac{9}{16}$ in. high.

Micro Switch, Freeport, Ill.



THE DARK CASED, SNAP-ACTION, PRECISION SWITCH is normally operated by the cabinet or control box door. For testing purposes, the push rod is moved in manually.

For more information circle No. 3 on Reader Service Card

CONTINUED ON PAGE 164

Pre-Assembly Cuts Costs

...IMPROVES PERFORMANCE, TOO!

EXTERNAL

Lower costs are certain with SEMS-by-SHAKEPROOF because the costly operation of putting lock washers on screws by hand is completely eliminated.

INTERNAL

Specially designed Shakeproof Lock Washers provide positive vibration resistance.

COUNTERSUNK

Two parts are handled as one, even in flat or oval head screw applications.

THREE-PIECE

For even greater savings subsub assembly parts can be pre-assembled to screws!

SEMS-by-SHAKEPROOF

T. M. REG. U. S. PAT. OFF.

FEATURING SHAKEPROOF LOCK WASHERS WITH TAPERED-TWISTED TEETH!

SEND FOR THIS FREE SAMPLE KIT...

Learn why it is important to specify Shakeproof Lock Washers when ordering Sems—test this better fastener on your own product, now!

NEW

SHAKEPROOF POWER SCREW DRIVER

It's hopper fed . . . to reduce piece handling and assembly costs! Handles Sems units of any head style as well as ordinary screws and Shakeproof Thread-Cutting Screws. Assures proper tightening torque for maximum fastening efficiency. Write for illustrated folder today!

HAVE YOUR PRODUCT "FASTENING ANALYZED"

...a Shakeproof engineer study your product to see if improved ...ing methods can reduce your costs. Write for details, today!

SHAKEPROOF inc.

DIVISION OF ILLINOIS TOOL WORKS

2501 North Keeler Avenue, Chicago 39, Illinois

In Canada: Canada Illinois Tools, Ltd., Toronto, Ontario

Thermosetting Plastic Has Range of Flexibilities

High strength material is produced in flexibilities ranging between hard and soft rubber. Resistance to chemicals and abrasion is claimed superior to that of hard rubber in gear and bearing applications.

Development of a tough, thermosetting plastic which promises to become one of the basic raw materials of the rubber industry has been announced. The new plastic bridges the gap which has existed between soft rubber and hard rubber. It fulfills a need for high strength material which is resistant to abrasion and chemicals and at the same time can be produced in varying degrees of flexibility ranging between elastic soft rubber on one hand and brittle hard rubber on the other.

One of its outstanding uses is to replace metals in the manufacture of high strength, low-cost gears. Gears made of the new plastic have been operating for more than a year in applications where conventional metal gears have failed within a few weeks. These gears were molded in one piece to close tolerances which eliminated the need for elaborate finishing.

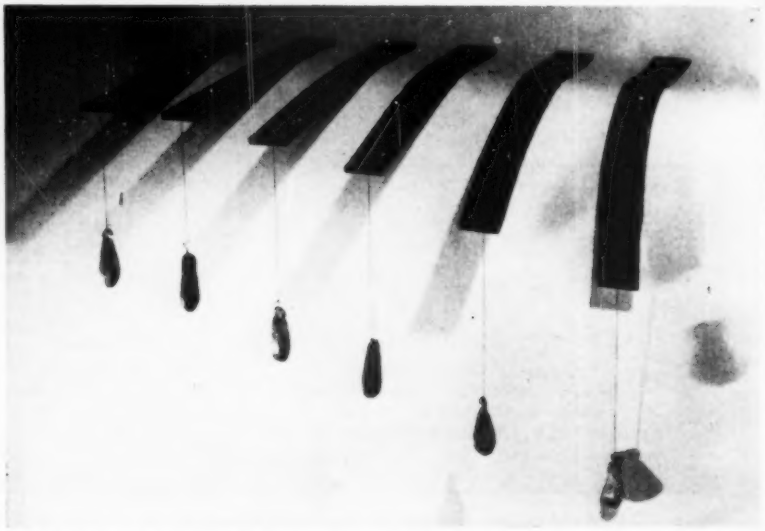
The new plastic will be marketed under the trade name "Enrup". It has an impact strength which is superior to most plastic materials and can be molded economically by either compression or transfer methods. Properties of one typical compound are listed in the table below. Sheets, rods, tubes, gear blanks and molded parts are available.

PHYSICAL PROPERTIES	
Specific Gravity	1.3
Tensile Strength, psi	4,200
Hardness Rockwell M	65
Impact Strength, Ft-lb/in. notch	1.3
Modulus of Elasticity	180,000
Water Absorption Percent Gain 24 hr	0.3
Fire Resistance	Fair
Safe Operating Temperature	180 to 250 F

RESISTANCE TO CHEMICALS	
Acid—Cold	Excellent
Acid—Hot	Good except oxidizing
Alkali—Cold	Good
Alkali—Hot	Fair
Solvents—	Excellent
Gasoline—	Good

ELECTRICAL PROPERTIES	
Dielectric Strength Volts/mil	500
Dielectric Constant	9
Power Factor	0.20
Arc Resistance	Good

United States Rubber Co., 1230 Ave. of Americas, New York 20, N. Y.



THE NEW PLASTIC has high impact strength and can be produced in varying degrees of flexibility. Extreme left is hard rubber, while on the extreme right is soft rubber. The four strips between are Enrup samples. Because of its toughness and elasticity, the new compound is expected to compete with hard rubber and phenolic plastics.

CLOSE-UP OF SOME OF THE PRODUCTS which have been molded out of the new thermosetting plastic. The smallest gear weighs ¼ oz., while the large, rectangular panel, 45 by 15 in., weighs 21 lb. Close tolerance molding is claimed to eliminate elaborate finishing operations. Machine elements are designed for high abrasion resistance.

For more information circle No. 4 on Reader Service Card

CONTINUED ON PAGE 166

MAKE A TON OF SHEET STEEL GO FARTHER

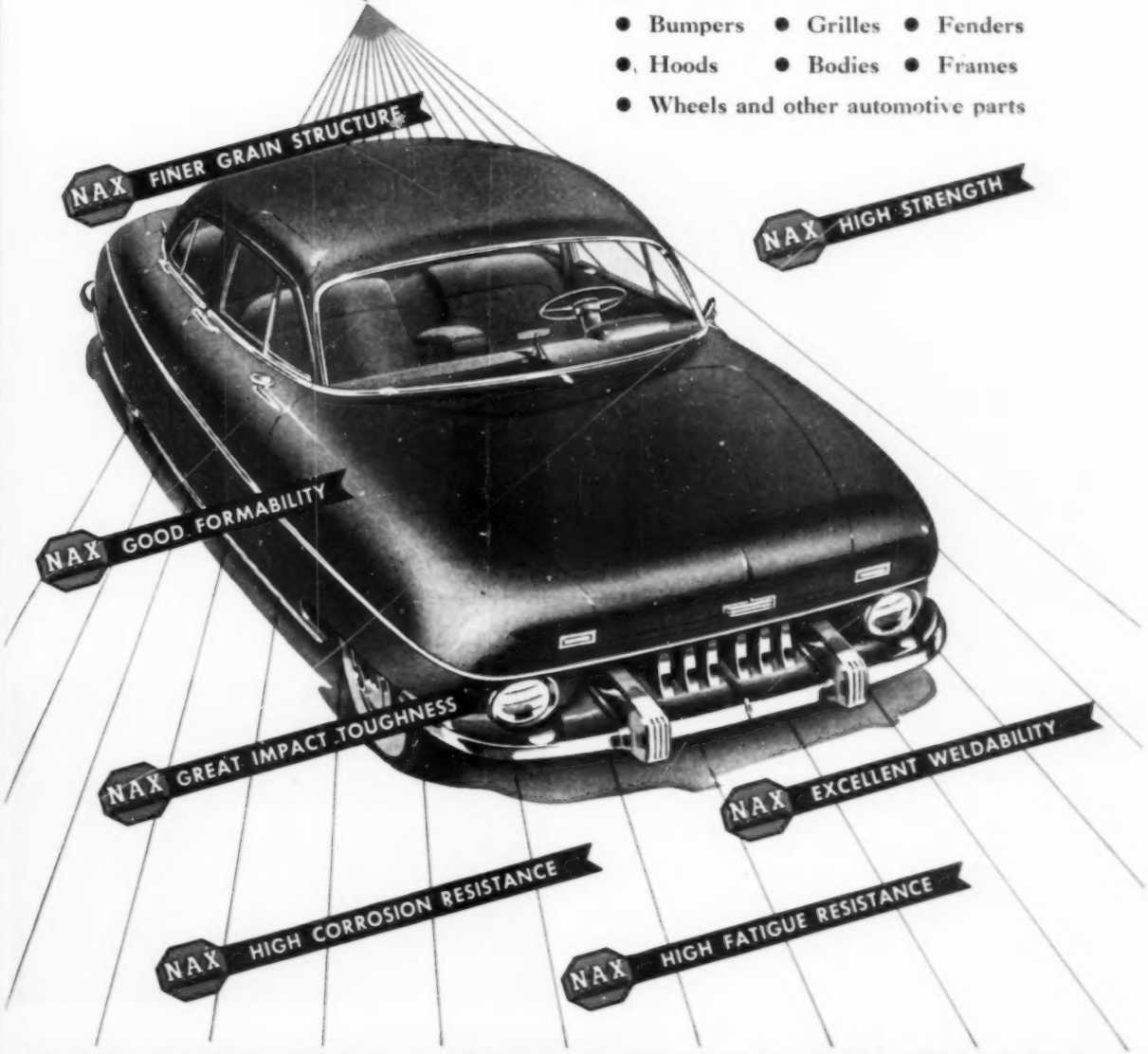
Specify—

N-A-X

HIGH-TENSILE STEEL

SEVEN STRONG REASONS explain the trend to N-A-X HIGH-TENSILE steel for:

- Bumpers
- Grilles
- Fenders
- Hoods
- Bodies
- Frames
- Wheels and other automotive parts



GREAT LAKES STEEL CORPORATION N-A-X ALLOY DIVISION • ECORSE, DETROIT 29, MICH. • UNIT OF NATIONAL STEEL CORPORATION

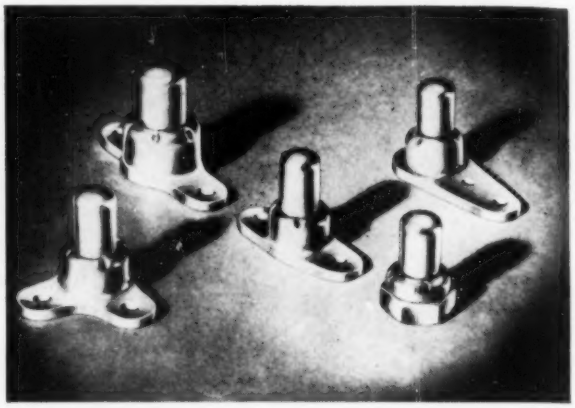
Extra High Nuts Reduce Bolt Variations

Extra high, lightweight, metal caps for certain of the manufacturer's hex and anchor nuts have been provided for airframe and component fabricators. The inside thread height of the cap nuts is sufficient to insure full clearance for AN-3 and AN-4 bolts, or AN-509 screws.

The manufacturer's intention has been to provide a nut which can be used with a single length of screw to join sections with permissible variations in thickness equal to the extra height of the new cap nuts. Within this limit, whatever the length of screw thread projection, these nuts will give at least the thread engagement of the shorter, standard, cap nut. Purchasing and assembly call-outs will be simplified by standardized screw lengths and cap nuts.

The manufacturer's usual red elastic collar and the new cap are designed as an effective pressure seal to 80 psi.

Elastic Stop Nut Corp., 2330 Vauxhall Rd., Union, N. J.



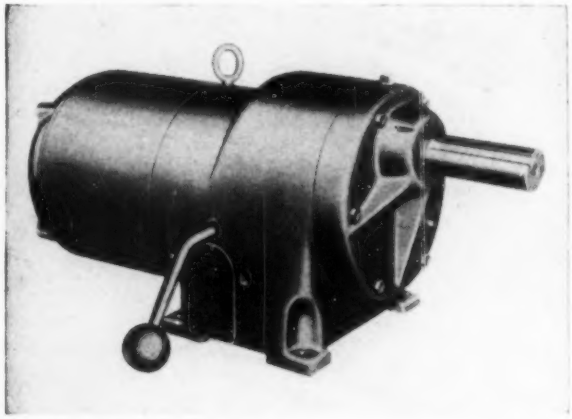
For more information circle No. 5 on Reader Service Card

Electric Gearshift Drives Have Four Speeds

This four-speed unit has been added to the manufacturer's line of gearshift drives. It consists of a combination integrally mounted electric motor and a four-speed transmission having both primary and secondary gear reductions. Full rated horsepower is delivered in each of the four speeds to give increased flexibilty of torque. Both constant-torque, and constant-horsepower two-speed motors are available.

Speed ranges vary from a four speed 93, 123, 207, 385 rpm output to a 418, 554, 932, 1730 rpm unit. A variety of 33 ranges is furnished in all, with horsepower ratings 1, 1½, 2, 3 and 5. Operation is from polyphase, a-c power supply of standard 25, 50 and 60 cycles and voltages below 600 volts. A variety of four possible primary gear ratios and eleven secondary give the range of speeds. Shift lever position varied to order.

Lima Electric Motor Co., Lima, Ohio



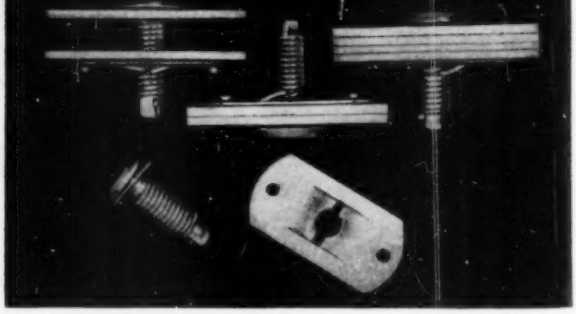
For more information circle No. 6 on Reader Service Card

Screw Fastener Absorbs Vibration and Shock

The new fastener is claimed by its manufacturer to be vibration proof under the most severe conditions of panel movement and shock. Working on the same principle as an ordinary bolt, this fastener employs a coil spring as a thread. In place of a nut, a specially punctured piece of flat metal is used to engage the spring threads.

As the fastener is turned down, spring tension is increased to hold the joint tighter. The illustration at right shows the new fastener used in several ways. As the flat metal nut contacts the bearing surface the spring is put into tension. The pressure holds the unit against loosening and provides a shock cushion. A variety of sizes are available.

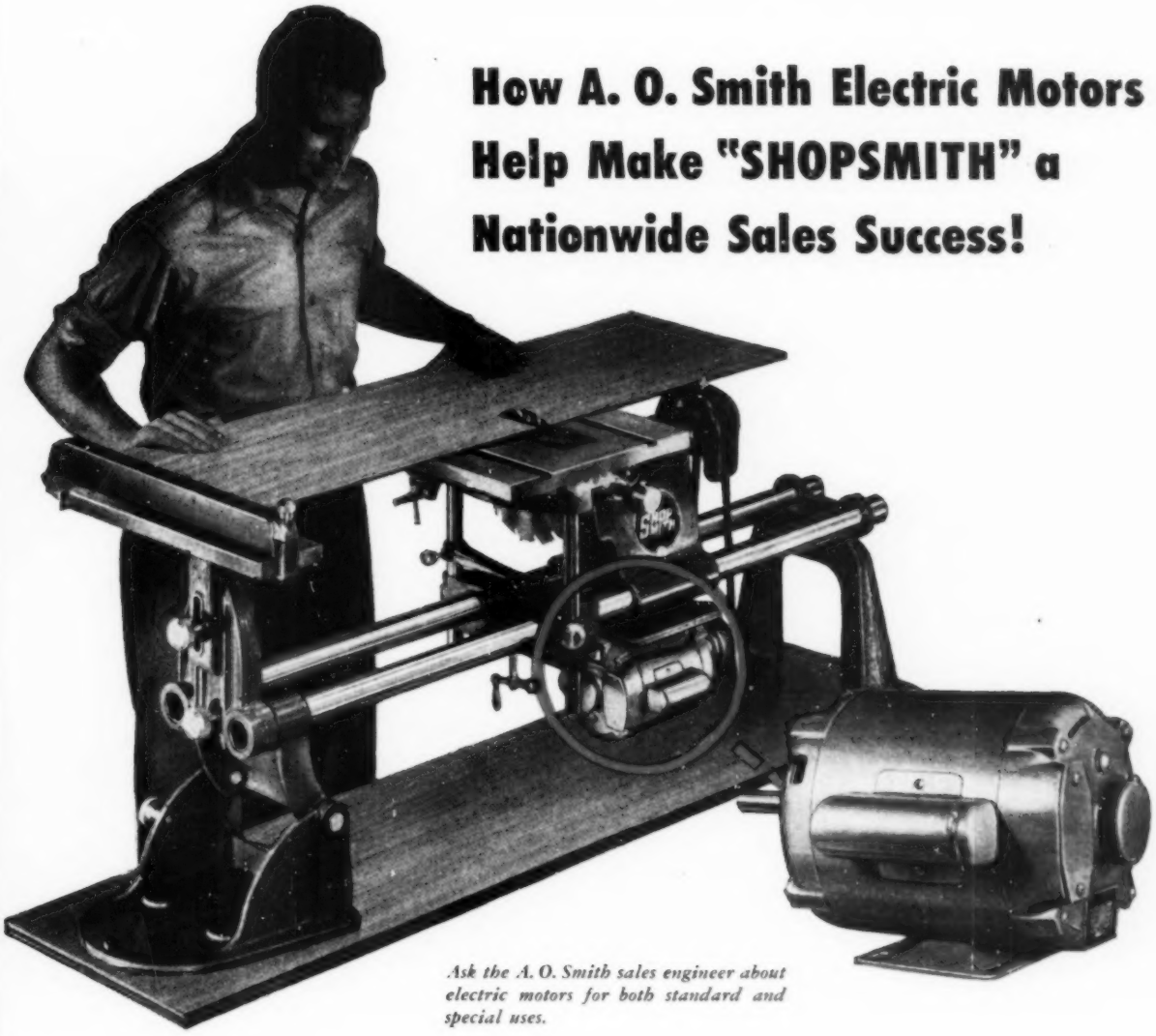
South Chester Corp., 1403 Finance Bldg., S. Penn Square, Philadelphia 22, Pa.



For more information circle No. 7 on Reader Service Card

CONTINUED ON PAGE 168

How A. O. Smith Electric Motors Help Make "SHOPSMITH" a Nationwide Sales Success!



Ask the A. O. Smith sales engineer about electric motors for both standard and special uses.

SHOPSMITH, ingenious 5-purpose woodworking tool, has proved an immediate hit with home and hobby craftsmen across the nation. For less than $200, in less than 8 sq. ft. of floor space, SHOPSMITH is 8" circular saw, 12" disc sander, horizontal or vertical drill press, and 33" wood lathe—all in one. Tool-to-tool change takes less than 60 seconds.

The A. O. Smith Electric Motor, which now powers more than 50,000 SHOPSMITHS, was designed after exhaustive operating tests by A. O. Smith engineers and SHOPSMITH'S makers, Magna Engineering Corp., San Francisco.

Many special features were required to provide a single-purpose motor for the multiple-purpose tool. Prime performance requirements for the ½-hp electric motor were six:

1. Special torque characteristic to carry through "hard spots."
2. Starting switch designed to permit automatic overload protection for short periods without danger of burnouts.
3. Totally enclosed end-bell to protect switch contacts from sawdust, shavings, dirt.
4. Base designed to allow maximum tool-swing.
5. Capacitor located out of the operator's way.
6. Attractive finish to enhance over-all SHOPSMITH appearance.

A. O. Smith offers complete development and production facilities for special-purpose electric motors to meet the requirements of your particular application. Perhaps you must have special torques or temperature ratings . . . small space and weight for a given hp . . . or distinctive appearance to match the style of your product and give you a distinctive sales feature.

Our engineers are ready to work with you. Call any A. O. Smith sales office, or write for information to Dept. PE-650, 5701 Smithway St., Los Angeles 22.

• • •

24-HOUR MOTOR SERVICE. *To more than 200 authorized service stations, A. O. Smith Product Service Division provides fast, low-cost service, on a 24-hour, off-the-shelf basis. Factory Service Branches and Warehouses at Union, N. J., Chicago 17, Dallas 2, Los Angeles 12.*

76½ ANNIVERSARY 1874 · 1950

A.O.Smith

ELECTRIC MOTORS

Atlanta 3 • Boston 16 • Chicago 4 • Dallas 1 • Dayton 4 • Denver 2 • Detroit 2 • Houston 2
Los Angeles 14 • Milwaukee 1 • New York 17 • Pittsburgh 19 • Salt Lake City 1
San Francisco 4 • Seattle 1 • Tulsa 3 • Washington 6, D. C. • International Division: Milwaukee 1

Metal-Ceramic Has Combination Properties

This new commercial metal-ceramic is a combination of 70 percent aluminum oxide ceramic and 30 percent powdered chromium and exhibits properties not available in either metals or ceramics alone. Thermal conductivity and shock resistance are increased by the metal, while the ceramic resists high-stress, high-temperature deformation and affords protection for the chromium from oxidation and solution attack. The trade name of the material is "Metamic LT-1."

The new ceramic is only superficially attacked by molten steel and furnace slag and has good resistance to molten brass and bronze. It is resistant to combustion gases up to 3,100 F and to oxidation at 2,200 F in air. Argon and nitrogen have been injected into carbon and stainless steels with the new material, but it is unsatisfactory for injecting oxygen into molten steel. Rapid attack occurs with molten glass and alkaline vapors at 2,600 F. Under some circumstances, use with molten aluminum has also been found unsatisfactory.

Strength is retained at temperatures from 1800 to 2,500 F. The new material is superior to most ceramics in thermal shock resistance, although inferior to metals in this respect. Small pieces give the best thermal shock performance. Manufacturer's tests have found that 0.1 by 0.25 by 1.5 in. bars can survive, without loss of strength, 24 cycles of heating to 2,552 F in 5 sec in a blowpipe flame, followed by airblast cooling to 1,292 F in 5 seconds. Faster heating and cooling, or the same test on larger specimens, might result in cracking.

The metal-ceramic is more brittle than metals. Articles may break if dropped on a concrete floor. In short-time tests below temperatures of 1800 F, the new material has shown higher allowable fiber stresses than pure aluminum oxide ceramics. Up to 2,500 F, creep characteristics approach those of the pure oxide material.

The new products are fabricated by powder metallurgy techniques and cannot be worked by rolling, forging or drawing. Intricate shapes are produced by the use of cores and multi-piece molds, taking the usual care to avoid sharp corners without fillets. Parts up to 2 in. in diameter by 18 in. long can be produced at present. It is desirable to stay below a length-to-diameter ratio of 30 for rods, and a length to thickness ratio of 30 for plate parts. In thin-wall tubes, diameter-to-wall thickness should be less than 8, and wall thicknesses of less than $\frac{1}{16}$ in. are difficult to produce. The new material is machinable, as shown.

Haynes Stellite Div., Union Carbide and Carbon Corp., 30 E. 42nd St., New York 17, N. Y.

THE NEW METAL-CERAMIC can be threaded and bolts can be fabricated. These tend to be brittle however. Ceramic-to-steel joints are made with pressure welding and copper-brazing.

Comparative Properties of Metal-Ceramic

	"Metamic LT-1"	Cast Iron	Pure Sintered Alumina
Density (lb per cu in.)	0.22	0.26–0.29	0.15
Melting Point (deg F)	3362	2066–2500	3722
Mean Coefficient Thermal Expansion (per deg F)	0.0000047	0.0000062	0.0000043
Hardness (Rockwell C)	35	18–21	shatters
Short Time Bending Strength (psi)–			
77 deg F	50,000	90,000	40,000
1,832 deg F	38,000	Oxidizes	35,000
1,400 deg F	15,000	Molten	15,000
Impact Strength 77 deg F (in-lb)	11	73	7
Thermal Conductivity (cgs units, 300 deg F)	0.12	0.11	0.007
Electrical Resistivity Microm-cm (70 deg F)	87.	10.	0.000000000010

For more information circle No. 8 on Reader Service Card

Mineral-Filled Phenolic Stands Up to 450 F

Claims made for this new mineral-filled phenolic molding compound include excellent heat resistance, good finish, fast cure, and a relatively low specific gravity, in comparison with most heat-resistant materials. The new material has good strength characteristics and is suitable for molding around inserts. Molded test pieces which have been baked for 24 hours at 450 F are stronger after the test and retain their high-gloss finish. After 200 hours at 450 F, the surface appearance of the material is still relatively unimpaired. Intermittent exposure to higher temperatures is equally safe. High-frequency preheating characteristics are similar to those of other mineral-filled materials. The material can be molded either by the compression or plunger methods, and its fast cure is designed to give molding economy.

Durez Plastics & Chemicals, Inc., North Tonawanda, N. Y.

For more information circle No. 9 on Reader Service Card

CONTINUED ON PAGE 170

"Commercial" Ball-Bearing Data...#8 of a Series

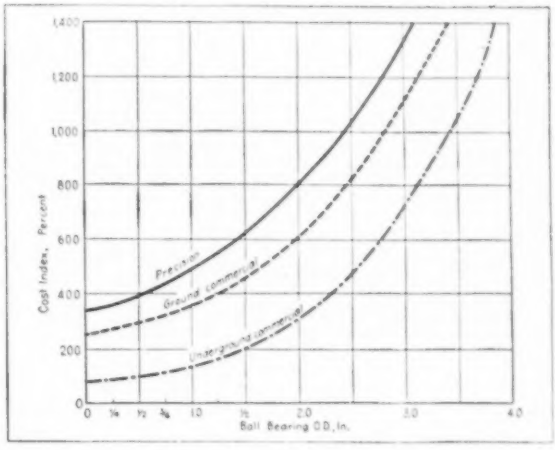
WE WILL BE GLAD TO SEND YOU COPIES OF THE PREVIOUS ADVERTISEMENTS IN THIS SERIES.

Schatz "Commercial" Ball Bearings can reduce anti-friction bearing costs 35 to 85%

Expensive precision bearings with their extremely close tolerances are often unnecessary in certain applications.

Where the operating conditions of these applications are within the load and speed limits of Schatz "Commercial" Ball Bearings, you can obtain the required anti-friction bearing performance—at ⅔ to ⅙ the cost of precision bearings.

The savings possible in such instances are illustrated in the graph at the right.



Relative costs of precision and "Commercial" Ball Bearings. In very small sizes, the cost of precision bearings *increases* as the bore decreases, due to the difficulty in maintaining close tolerances. The cost of "Commercials" *decreases* in almost direct proportion to the size.

Schatz "Commercial" Ball Bearings are classified as follows:

UNGROUND—FOR LIGHT LOAD, LOW-SPEED OPERATION—the lowest-cost ball bearing available.

GROUND—2.17 TIMES THE RADIAL LOAD-CARRYING CAPACITY OF UNGROUND TYPE. Inner and outer races are ground to superfine finish for smoother, faster operation and heavier loads.

SPECIAL BEARINGS—ENGINEERED TO SPECIFIC NEEDS—often at no greater cost than standard types. Various modifications—in materials, inner ring, outer ring and ball arrangement—make it possible to use a special bearing where no standard type can fill the requirements. Costly machining and assembly time required for bushings or plain sleeve bearings is eliminated.

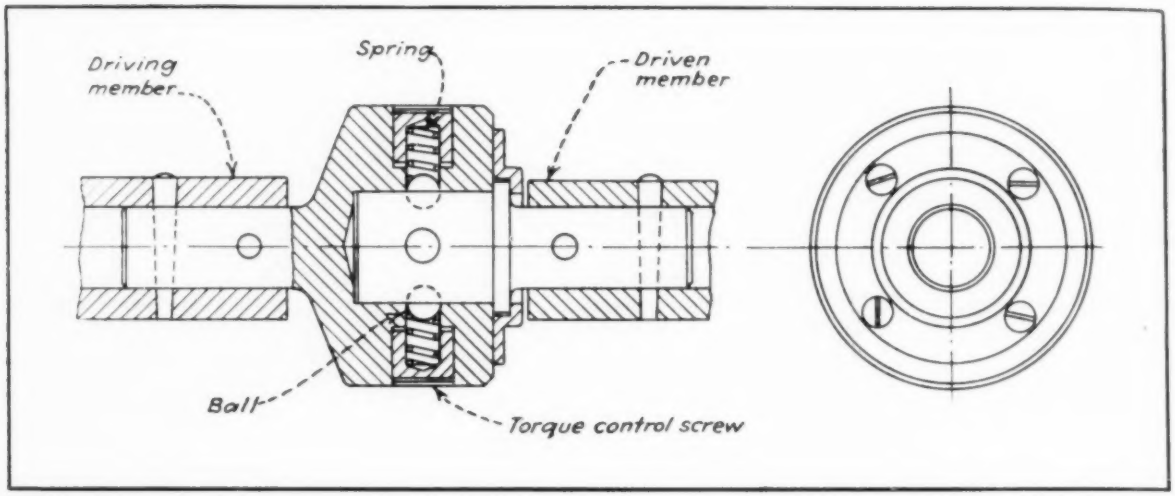
All Schatz "Commercial" Ball Bearings, single or double row, can be equipped with felt or labyrinth seals, flanged or plain outside diameters, hardened or unhardened treads, set screws, Alemite fittings, extended inner ring and hexagonal bore.

Write for your copy of "Construction and Characteristics of Low-Cost Ball Bearings." It tells how to select "Commercial" Ball Bearings for various speed and load requirements, gives the classifications of standard types for radial and thrust loads, and examples of the modifications that can be made for special design, assembly or operating conditions. Ask for Catalog No. 11, too. It gives complete data for the whole "Commercial" line.

SCHATZ
"Commercial"
BALL BEARINGS

The Schatz Manufacturing Company
6758 FAIRVIEW AVENUE, POUGHKEEPSIE, N. Y.

Torque Overload Control Can Disengage at 1 In-lb



IN THIS MODEL the overload control is attached to shaft members by taper pins. The torque control screws vary the pressure of the balls on the driven members and in this way allow for adjustment of overload torque by changing spring pressure. In normal operation the driven member is held by the clamping action of the balls. Overload allows the shaft to slip.

This overload control is designed to protect the driven member from damage in case of overloading or a sudden interference with normal operation. As soon as the driven member is free to turn again, at normal load, the new control is automatically re-engaged and the member is driven normally.

The inner member is hardened and ground, with close tolerances held between the moving parts. The balls are hardened and polished. According to the manufacturer, there is practically no wear on the moving parts.

The overload control can be made to disengage at torques as low as 1 in-lb, and can be furnished to carry any desired load. The smallest size is ½ in. long and ½ in. in outside diameter. With few parts, manufacturing costs are said to be low. The cost to the customer depends mainly on the required loads, which determine the size of the unit. Various models can be furnished to suit mounting needs.

Overload Control Co., 260-63 Langston Ave., Floral Park, N. Y.

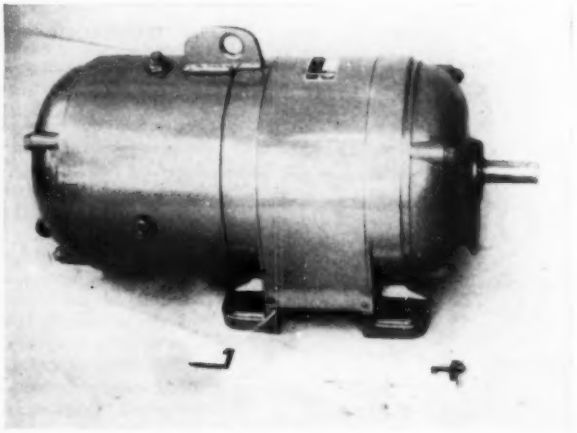
For more information circle No. 10 on Reader Service Card

Vacuum Rectifier Excites Alternator

This new single or three phase homopolar inductor alternator with electronic exciter regulator is designed to provide a voltage regulation of plus or minus 1 percent. The motor component is a low-slip induction motor calculated to keep frequency within plus or minus ½ percent.

Used as a power supply for electronic gear, such as radar, x-ray, calculators, induction heaters, etc., and for motor drives on high speed machine tools and instruments, the new alternator is available in sizes up to 10kw, with frequencies up to 1500 cycles, and can be supplied either self-ventilated, or water-cooled for dusty, or hazardous locations.

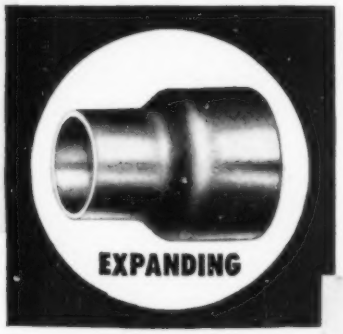
Excited by vacuum rectifiers, the machine is claimed to be independent of line frequency fluxuation. A minimum of maintenance is expected in view of the absence of springs, brushes and commutators.



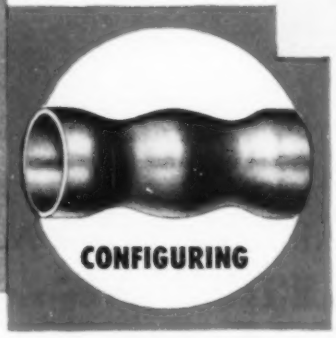
American Electric Motors, Inc., 4811 Telegraph Rd., Los Angeles 22, Calif.

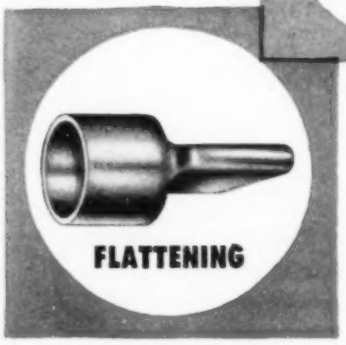
For more information circle No. 11 on Reader Service Card

CONTINUED ON PAGE 172



Severe Fabrication?





ELECTRUNITE TUBING
...Takes it with ease

There's a mighty good reason why ELECTRUNITE Tubing stands out for forming operations like these. It's Republic's ELECTRUNITE Process in which highest quality flat rolled steel is cold formed and welded into strong, sound tubing. As a result every length is uniform throughout—in roundness, diameter, wall thickness and ductility . . . free from defect, inside and out.

Republic ELECTRUNITE Tubing is available in a full range of sizes, gages and analyses—both carbon and stainless steels. See your nearest Steel and Tubes Representative or write today for a free copy of booklet No. 22.

REPUBLIC STEEL CORPORATION
STEEL AND TUBES DIVISION • CLEVELAND 8, OHIO
Export Department: Chrysler Building, New York 17, N.Y.

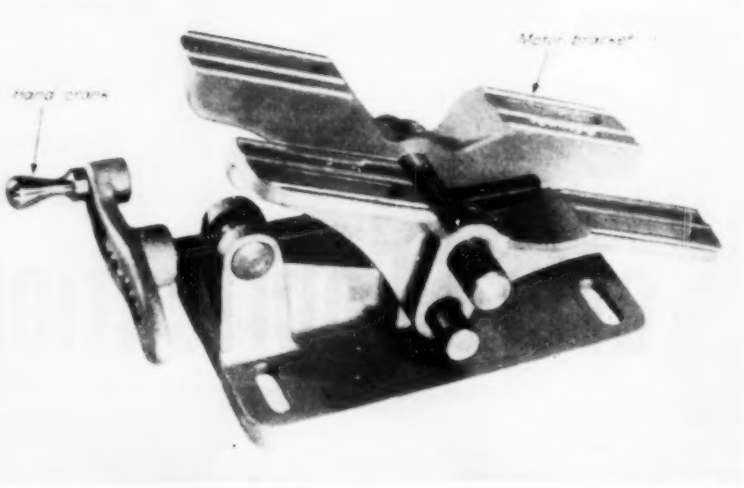
Republic REPUBLIC STEEL

ELECTRUNITE TUBING

Fractional Hp Motor Base Tilts To Vary Speed

This fractional hp motor base is tilted by manipulation of the hand crank screw mechanism. The motor brackets are pivoted about the lower base shaft by the screw action to change the position of the motor shaft. The unit is intended for adjustment of shaft centers with variable speed pulley drives in product designs requiring a minimum of adjustment space.

Light duty motors up to $\frac{3}{4}$ hp are accommodated. The manufacturer's standard variable speed pulleys can be furnished for $\frac{1}{6}$, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$ and $\frac{3}{4}$ hp motors. Full play of the base will tilt the motor 28 deg from vertical in one direction and 8 deg in the other. The weight of the complete base is 10 lbs. For the smaller motors, the motor brackets are toed-in to give a minimum mounting-bolt center distance of $1\frac{1}{2}$ inches. Brackets shown toed out.

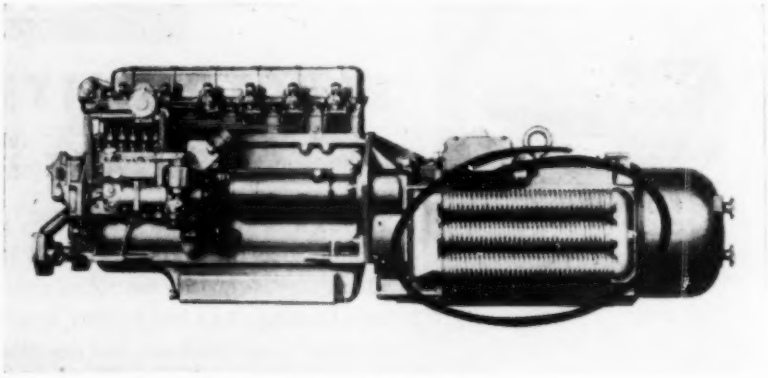


Gerbing Mfg. Corp., 630 W. Washington Blvd., Chicago 6, Ill.

For more information circle No. 12 on Reader Service Card

Flexible Metal Hose Acts As Heat Exchanger

This corrugated metal hose is offered for use in cooling systems and heat exchanger equipment. The hose is made up in annular corrugations from bronze strip. Re-usable, mechanically attached couplings, together with brazed, welded and soldered fittings are offered for use at high pressures and temperatures. The heat-exchanger hose is offered in 14 sizes, varying from $\frac{3}{16}$ to 4 in. inside diameter. Bursting pressures increase as the hose size decreases, from 8,000 psi in the $\frac{3}{16}$ in. to 350 psi in the 4 in. hose.



Chicago Metal Hose Corp., Maywood, Ill.

For more information circle No. 13 on Reader Service Card

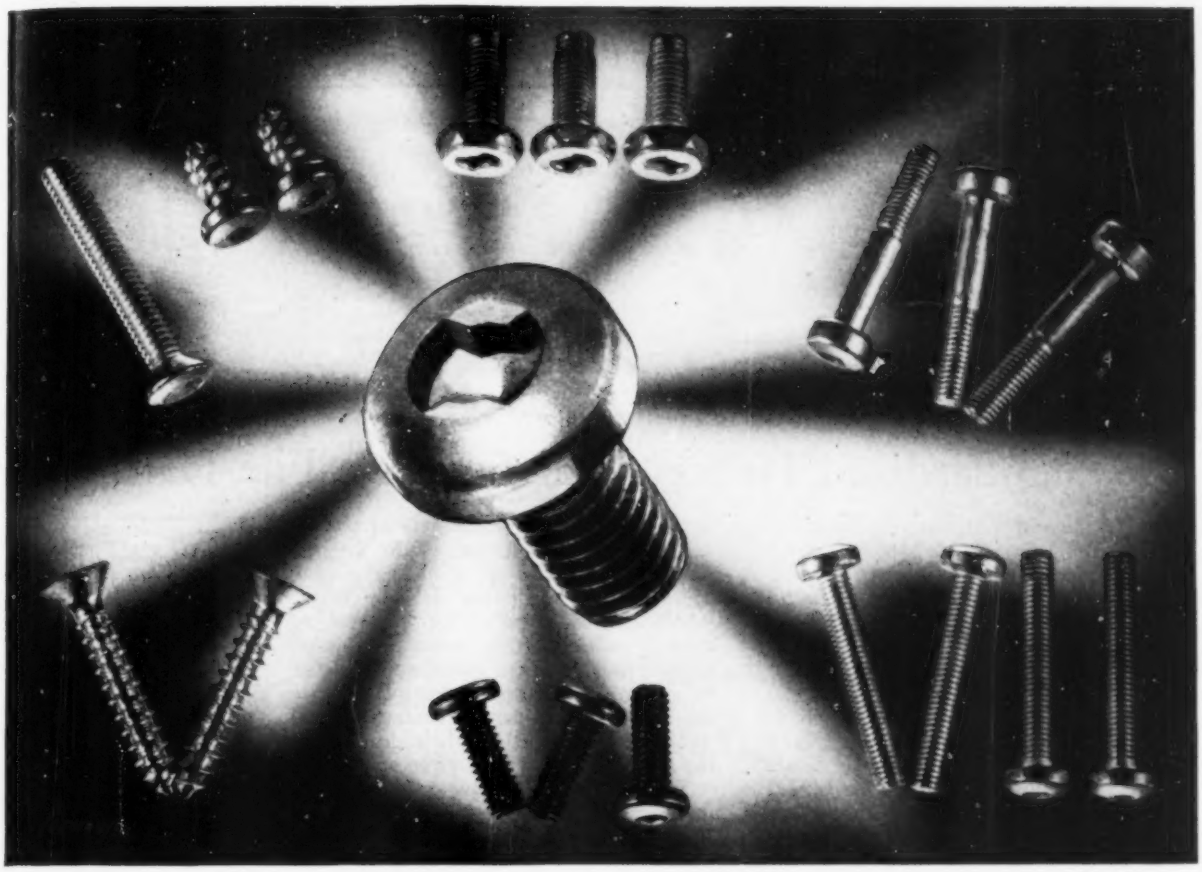
Terminal Block Holds Wire Without Solder

There are no terminals to apply to wire ends or studs to wrap wires around with this solderless type molded terminal block. Wire preparation is held to a minimum. The stripped conductor is inserted into the two piece terminal clamp and the holding screw is tightened down to give a firm connection. Wire sizes from No. 16 to 6 AWG are accommodated. Since each conductor is held in an individual clamp, any combination of wire sizes can be used in circuits connected through the new terminal block. Screw-on covers are available to facilitate inspection and provide protection for terminals. A lead-in wire in any circuit can be disconnected by loosening the single holding screw without disturbing the terminal of the out lead of the same circuit. This allows re-connecting and testing with minimum confusion and maximum safety. The new blocks are rated at 35 amps, 600v and are available in 4, 8, and 12 circuit sizes.

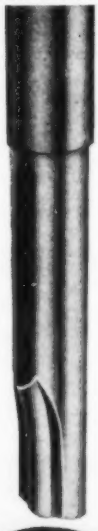
Buchanan Elec. Products Corp., 1290 Central Ave., Hillside, N. J.

For more information circle No. 14 on Reader Service Card

CONTINUED ON PAGE 174



TYPE "A" ASSEMBLY BIT



COMMON SCREWDRIVER

A Sevenfold Reason Why CLUTCH HEADS *Drive Assembly Costs Down*

I The higher visibility of the wide roomy clutch recess frees the line from operator hesitation. Even "green" help drives with speed and confidence.

II Dead-center entry with the Center Pivot Column prevents driver canting and makes straight driving automatic . . . hence no burred or chewed-up heads.

III CLUTCH HEAD'S exclusive non-tapered driving engagement sends skid damage to zero. With no end pressure needed to combat "ride-out" (as set up by tapered driving) a fatigue factor is eliminated . . . with resultant higher production.

IV Only CLUTCH HEAD has a frictional Lock-On that joins screw and bit as a unit for easy one-handed reaching into inner spots and driving from any angle.

V Consider the unmatched durability of the Type "A" Assembly Bit with its record of 214,000 screws driven non-stop without interruption for tool changes.

VI Add to this the economy of simplified reconditioning of this bit *REPEATEDLY* . . . by a 60-second application of the end surface to a grinding wheel.

VII For simplified field service, CLUTCH HEAD alone has a recess basically designed for operation with any flat blade which is reasonably accurate *in width.*

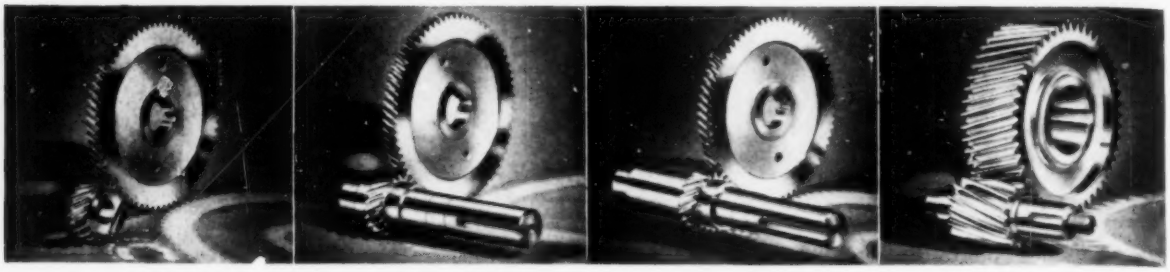
These and other cost-reduction features explain why users of America's Most Modern Screw credit change-over to CLUTCH HEAD *(from other types of recessed head screws) with assembly increases ranging from 15% to 50%.*

CLUTCH HEAD · SCREWS ·

These advantages are detailed and illustrated in the New CLUTCH HEAD *Brochure. Start your investigation of* CLUTCH HEAD'S *potential savings for you by sending for your copy . . . and indicate sizes and types of screws in which you are interested.*

UNITED SCREW AND BOLT CORPORATION

CLEVELAND 2 CHICAGO 8 NEW YORK 7



Type AN Drive | Type BN Drive | Type CN Drive | Type DW Drive

Standardized Helical Gear Sets Are File Hard

A new line of gear sets may be selected from simplified selection tables that take into account required hp capacity, service conditions and life expectancy. Selection procedure is comparable to selecting anti-friction bearings.

These gears are in quantity production and are available in approximately 200 combinations with ratios from 1.5 to 9.3 and center distances from 2.7 to 15.5 in. Capacities range from fractional up to several hundred hp. Gearing is available in four basic pinion constructions and two gear types for maximum flexibility in application.

A result of the file-hard tooth surfaces, tough, resilient cores and improved manufacturing techniques is lower cost. These superior gear units can be purchased for less than conventional gear sets that do not make as effective use of materials. Other savings in the cost of housing and associated parts are obtained by the more compact size of these gear sets.

Suggested applications of this gearing cover practically the entire field of parallel shaft power transmission within the size range offered. The use of this gearing is of particular importance in new design where size is controlled by the gear set capacity rather than by externally imposed limitations and where minimum cost must be achieved. A second important use is in the replacement of parallel shaft gearing of softer steel construction where gear failure has been a problem for a given application.

Type A, B and C pinions in the above drives mate interchangeably with Type N gear. Type D pinion mates with Type W gear. Type N gear can be mounted on D pinion shaft for double reductions. Shaft type pinions carry standard ball bearing diameters.

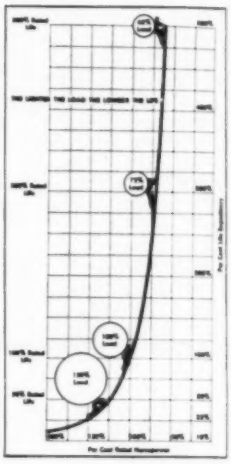
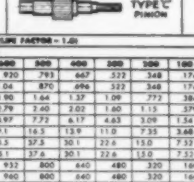


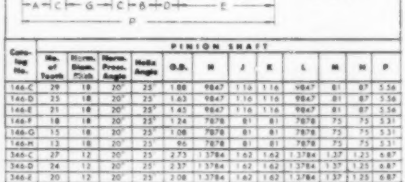
Chart at the right illustrates the relationship between the load carried and life expectancy. As the load is lightened, gear life is increased. Heavier loads bring a sharp reduction in service life. The chart below lists hp ratings for gear sets at integral pinion speeds. These tables are made possible by intensive stress and fatigue analysis and experimentation.

Foote Bros. Gear & Machine Corp., 4545 S. Western Blvd., Chicago 9, Ill.



RATIO		Center	CATALOG HORSEPOWER RATINGS (LIFE FACTOR = 1.0) R.P.M. OF PINION												CATALOG NUMBER PINIONS			
Nom.	Actual	Distance	3600	3000	2400	1800	1500	1200	900	720	600	500	400	300	200	100	Type A	Type B	Type C	Gear
3.00-1	5.000	2.415	3.60	3.21	2.71	2.22	1.91	1.60	1.27	1.10	920	793	667	522	348	174	109-H	146-H	147-H	110-C
	5.133	2.875	4.72	4.21	3.55	2.92	2.52	2.09	1.57	1.30	1.04	870	696	522	348	174	109-G	146-G	147-G	110-G
	5.056	3.375	7.40	6.60	5.59	4.57	3.94	3.30	2.62	2.27	1.90	1.64	1.37	1.09	.772	386	209-G	246-G	247-G	210-G
	5.067	4.125	10.9	9.70	8.30	6.71	5.78	4.86	3.86	3.34	2.79	2.40	2.02	1.60	1.15	.578	309-G	346-G	347-G	310-G
	5.211	5.421	33.0	31.2	26.3	21.6	18.6	15.6	12.4	10.7	8.97	7.72	6.17	4.63	3.09	1.54	409-G	446-G	447-G	410-N
	5.067	6.438	74.9	66.7	56.9	46.0	39.8	33.3	26.5	22.9	19.1	16.5	13.9	11.0	7.35	3.68	509-G	546-G	547-G	510-G
	5.063	9.000	169.0	152.0	129.0	105.0	90.4	75.8	60.2	52.1	43.5	37.5	30.1	22.6	15.0	7.52	609-G	646-G	647-G	610-G
	5.000	16.590	262.0*	210.0*	175.0*	135.0	113.0	90.3	67.7	56.4	45.1	37.6	30.1	22.6	15.0	7.52	609-C	646-C	647-C	610-K
3.50-1	5.308	2.537	3.64	3.21	2.73	2.24	1.96	1.62	1.29	1.12	932	800	640	480	320	160	109-H	146-H	147-H	110-D
	5.333	2.944	4.80	4.27	3.64	2.88	2.40	1.92	1.44	1.20	960	800	640	480	320	160	109-G	146-G	147-G	110-H
	5.500	3.598	5.76	4.80	3.84	2.88	2.40	1.92	1.44	1.20	960	800	640	480	320	160	109-F	146-F	147-F	110-J
	5.700	6.200	19.2	16.0	12.8	9.50	7.98	6.38	4.79	3.99	3.99	2.66	2.13	1.60	1.06	532	309-E	346-E	347-E	310-J
	5.875	5.085	23.5	21.0	17.8	14.5	12.5	10.5	8.32	7.21	6.02	5.19	4.36	3.46	2.49	1.42	409-H	446-H	447-H	410-G
	5.429	9.336	93.3	82.4	68.9	54.7	47.3	39.6	30.4	25.4	20.3	16.9	13.5	10.1	6.76	3.38	609-E	646-E	647-E	610-J
	5.600	11.379	93.3*	82.4	68.9	54.7	47.3	39.6	30.4	25.4	20.3	16.9	13.5	10.1	6.76	3.38	509-D	546-D	547-D	510-K
	5.550	13.325	227.0*	196.0*	164.0	124.0	104.0	83.1	62.3	51.9	41.5	34.6	27.7	20.8	13.8	6.92	609-E	646-E	647-E	610-J
6.20-1	6.154	2.875	3.70	3.30	2.79	2.28	1.97	1.65	1.28	1.06	852	710	568	426	284	142	109-H	146-H	147-H	110-H
	6.200	3.375	5.72	5.10	4.34	3.53	3.05	2.55	2.03	1.76	1.47	1.26	1.06	843	606	315	209-H	246-H	247-H	210-H
	6.103	4.125	8.63	7.71	6.60	5.33	4.60	3.86	3.06	2.65	2.21	1.91	1.60	1.27	915	472	309-H	346-H	347-H	310-H
	6.706	6.062	17.0	14.2	11.3	8.50	7.08	5.66	4.25	3.54	2.83	2.36	1.89	1.42	944	472	309-F	346-F	347-F	310-J
	6.188	5.250	23.9	21.3	18.1	14.7	12.7	10.7	8.47	7.36	6.12	5.28	4.46	3.52	2.52	1.26	409-H	446-H	447-H	410-H
	6.711	6.438	53.1	49.0	41.8	33.9	29.3	24.6	19.5	16.9	14.1	12.2	10.2	8.10	5.82	3.00	509-H	546-H	547-H	510-H
	6.333	9.115	86.6	74.8	62.6	49.7	43.0	35.9	27.0	22.5	18.0	15.0	12.0	9.00	6.00	3.00	509-F	546-F	547-F	510-J
	6.222	9.000	121.0	108.3	92.3	74.9	64.6	54.2	43.0	37.2	31.1	26.8	22.5	17.9	12.3	6.16	609-H	646-H	647-H	610-H
	6.470	13.004	206.0*	178.0	147.0	110.0	92.1	75.7	55.3	46.0	36.8	30.7	24.6	18.4	12.3	6.16	609-F	646-F	647-F	610-J

*Indicates peripheral pitch line velocities in excess of 3,000 F.P.M. Gears are satisfactory for these speeds, but bearings and lubrication may need special consideration.



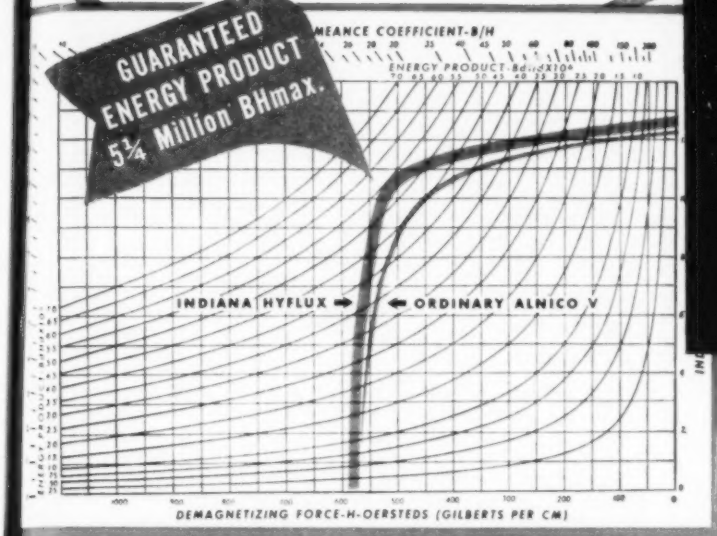
Catalog No.	PINION SHAFT No. of Teeth	Norm. Diam. Pitch	Norm. Press. Angle	Helix Angle	O.D.	N	J	K	L	M	N	P
166-C	29	18	20°	25°	1.88	.9847	1.16	1.16	.9847	81	87	5.56
166-D	25	18	20°	25°	1.63	.9847	1.16	1.16	.9847	81	87	5.56
166-E	21	18	20°	25°	1.43	.9847	1.16	1.16	.9847	81	87	5.56
166-F	18	18	20°	25°	1.34	.7878	81	81	.7878	75	75	5.31
166-G	15	18	20°	25°	1.08	.7878	81	81	.7878	75	75	5.31
166-H	13	18	20°	25°	.96	.7878	81	81	.7878	75	75	5.31
346-C	27	12	20°	25°	2.73	1.3784	1.62	1.62	1.3784	1.37	1.25	6.87
346-D	24	12	20°	25°	2.37	1.3784	1.62	1.62	1.3784	1.37	1.25	6.87
346-E	20	12	20°	25°	2.08	1.3784	1.62	1.62	1.3784	1.37	1.25	6.87
346-F	17	12	20°	25°	1.81	1.1815	1.37	1.37	1.1815	1.12	1.00	6.37
346-G	15	12	20°	25°	1.54	1.1815	1.37	1.37	1.1815	1.12	1.00	6.37
346-H	19	18	20°	25°	1.27	1.1815	1.37	1.37	1.1815	1.12	1.00	6.37
546-C	29	8	20°	25°	4.25	1.9689	2.31	2.31	1.9689	1.81	1.87	9.31
546-D	25	8	20°	25°	3.70	1.9689	2.31	2.31	1.9689	1.81	1.87	9.31
546-E	21	8	20°	25°	3.24	1.9689	2.31	2.31	1.9689	1.81	1.87	9.31
546-F	18	8	20°	25°	2.76	1.5752	1.87	1.87	1.5752	1.56	1.50	8.56
546-G	15	8	20°	25°	2.48	1.5752	1.87	1.87	1.5752	1.56	1.50	8.56
546-H	19	12	20°	25°	2.03	1.5752	1.87	1.87	1.5752	1.56	1.50	8.56
646-C	30	6	20°	25°	5.93	2.7565	3.25	3.25	2.7565	2.75	2.62	11.87
646-D	26	6	20°	25°	5.19	2.7565	3.25	3.25	2.7565	2.75	2.62	11.87
646-E	22	6	20°	25°	4.55	2.7565	3.25	3.25	2.7565	2.75	2.62	11.87
646-F	19	6	20°	25°	3.91	2.1638	2.50	2.50	2.1638	2.12	2.00	10.62
646-G	16	6	20°	25°	3.36	2.1638	2.50	2.50	2.1638	2.12	2.00	10.62
646-H	18	8	20°	25°	2.77	2.1638	2.50	2.50	2.1638	2.12	2.00	10.62

For more information circle No. 15 on Reader Service Card

CONTINUED ON PAGE 176

...with New INDIANA HYFLUX PERMANENT MAGNETS

Now 22% More Energy for Alnico V AT NO EXTRA COST


GUARANTEED ENERGY PRODUCT 5¾ Million BHmax.
INDIANA HYFLUX ➡
⬅ ORDINARY ALNICO V
DEMAGNETIZING FORCE-H-OERSTEDS (GILBERTS PER CM)

DEMAGNETIZATION AND ENERGY PRODUCT CURVE

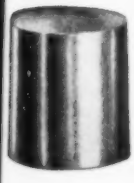
The Stronger Magnets you've been hoping for ARE HERE!

Now it can be told! After years of research and months of field-testing, INDIANA announces exclusive new *super-strength permanent magnets* made of HYFLUX Alnico V. The industry's highest published guaranteed energy product for standard Alnico V has been 4½ million BHmax. Now, INDIANA guarantees much greater strength — 5¼ million BHmax, and the *average* energy product reaches 5½ million BHmax, or more. Yet, for these higher-energy HYFLUX magnets, you pay *not a penny* premium.

What is HYFLUX Alnico V? INDIANA HYFLUX is *not* a new alloy. It's the result of a new precision technique applied to *dependable* Alnico V . . . new procedures, controls, instrumentation, and equipment, and *precise supervision* over every step of production. Add to this the 42 years of permanent magnet experience and a long-term training program for personnel by the world's *largest* exclusive producer, and you have the background and reasons why INDIANA HYFLUX is so outstanding in *both* performance and value.

Find Out What HYFLUX Can Do! For *greater strength* . . . more compact designing . . . for the lower production costs these smaller, better magnets can bring to *your own* products, get all the facts today on amazing INDIANA HYFLUX. It's the *most important development* in permanent magnets since the introduction of Alnico V.

See what HYFLUX *does!*



When this standard R. M. A. No. 3 loud speaker magnet is INDIANA HYFLUX Alnico V with the minimum guaranteed energy product of 5¼ million BHmax, it has .7 decibels greater output than when made with 4½ million BHmax *regular* Alnico V. Similar improvements—in strength or size—apply to *all* applications. INDIANA HYFLUX is ready now to bring *you* these advantages.

For Cost-Cutting Engineering Aid,
Put Your Magnet Problems up to INDIANA.

THE INDIANA STEEL PRODUCTS COMPANY
Specialists in Packaged Energy Since 1908
SALES OFFICES: BOSTON, CHICAGO, CLEVELAND, LOS ANGELES, NEW YORK, PHILADELPHIA, ROCHESTER

INDIANA PERMANENT MAGNETS

THE INDIANA STEEL PRODUCTS COMPAI
DEPT. B-60, VALPARAISO, INDIANA

Please send me all the facts on INDIAN HYFLUX. I am interested in permane magnets for:

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Name .....

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Street .....

City .....*Zone*.....*State*.....

Combination Instrument Measures Low Vacuums

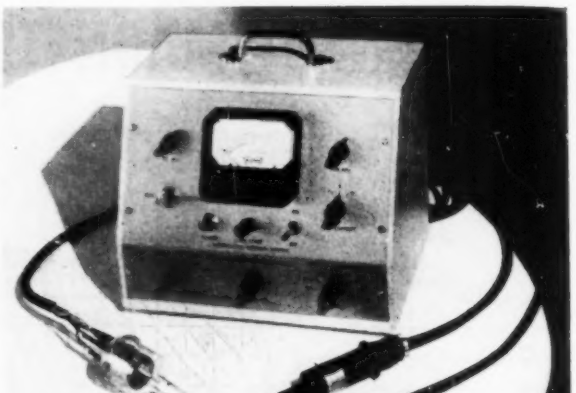
This instrument is designed to measure pressures between 1 and 1×10^{-9} mm Hg, Absolute. It employs two thermocouple type and one ionization type vacuum gages. One thermocouple is used on the high vacuum side of the pump and one on the low side.

The two thermocouple vacuum gages indicate pressures from 1 mm to 10^{-3} mm Hg Absolute directly on the instrument meter by responding to the temperature of a thermocouple junction which is supplied with constant heat. Due to the varying heat conductivity of the rarefied atmosphere, the temperature will be an exponential function of the pressure over the stated range. Measurements in this pressure range may be made at two points in the vacuum system by means of the two thermocouple gages.

One ionization type vacuum gage is used to cover the range from 5×10^{-3} to 1×10^{-9} mm Hg, Absolute. Gas ions formed by collisions with a controlled electron beam are collected in this gage and resulting ionization current is measured on the calibrated amplifier. Pressure, which is proportional to the number of ions formed, is indicated directly on the meter of the instrument. The ionization gage has five ranges with full-scale readings at 5×10^{-3}, 1×10^{-4}, 1×10^{-5}, and 1×10^{-6} mm with normal sensitivity. Normal sensitivity may be doubled for pressures below 5×10^{-7} mm.

A specially designed low-leakage shielded connecting cable is supplied to decrease errors at pressures below 10^{-6} mm where the ionization currents are less than 10^{-7} amp. This is important, since electrical leakage and pickup associated with standard cables are frequently not recognized by the plant or laboratory technician, who therefore reports pressure measurements which are incorrect.

A receptacle at the back of the chassis is connected so that auxiliary equipment such as alarm bells or relays in pump heater circuits can be controlled by the overload relay in the protective circuit for the ionization gage. The filament emission is regulated at 1, 5, or 10 milliamperes at the operator's choice. Small pressure changes spot leaks without emission readjustment.



INSTANTANEOUS PRESSURE bursts from 10^{-3} mm Hg. to atmospheric pressure have been survived more than 100 times by tests gages in manufacturer's tests. A protective relay with very short time delay automatically turns off the ionization gage filament when the pressure in the system exceeds one and one-half times the full-scale pressure for which the control is set.

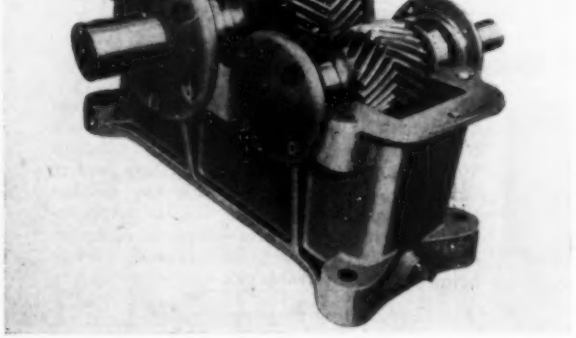
National Research Corp., 70 Memorial Dr., Cambridge, Mass.

For more information circle No. 16 on Reader Service Card

Herringbone Reducers Handle ½ to 1,000 Hp

These new herringbone gear speed reducers are available in single, double, and triple reduction units with capacities ranging from ½ to 1,000 hp and center distances from 4 to 36 in. All shafts turn on anti-friction bearings. The output bearings of standard torque units are designed to carry medium overhung loads. Double-row, tapered roller bearings are used with special overhung load types.

The gears are made of electric steel castings or high-carbon steel forgings. Pinions and pinion shafts are cut integrally from heat treated chrome-molybdenum steel. Efficiencies of over 98 percent are claimed for single reduction units. Applications are anticipated with conveyors, generators, blowers, pumps, machine tools, cranes, hoists and agitators. Single reduction unit is shown at right. The herringbone driver and driven gears are seen with the cover removed. Herringbone gear transmission is designed for even tooth engagement and avoids gear side thrust and unnecessary wear.



DeLaval Steam Turbine Co., Trenton 2, N. J.

For more information circle No. 17 on Reader Service Card

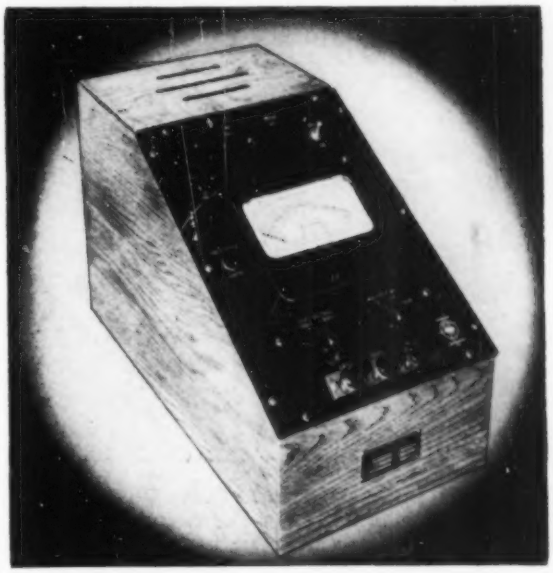
CONTINUED ON PAGE 177

Megohm Meter Maintains Constant Source Voltage

The new megohm meters feature an internal circuit designed to assure the user that the applied voltage is equal to the specified voltage as long as the resistance of the piece under test is within the range of the meter. Resistance tests may be conducted with a known voltage.

Two models are available in this meter. One contains an internal 500 v measuring source, together with a 200 v source. The other model is equipped with a continuously variable measuring source ranging from 100 to 600 v d-c. A volt meter is provided for checking actual voltage being applied to test. This second unit is designed to test for resistance changes as the voltage is varied.

The manufacturer intends these meters for production as well as laboratory work. Inclined control panels with specially designed meters and control markings are claimed to facilitate accurate, rapid readings. Two models similar to those listed above are available for applications which require a single constant-voltage test current. Within a given outside current resistance range, these instruments will compensate for external changes and hold the output voltage constant.



Industrial Instruments, Inc., 17 Pollock Ave., Jersey City 5, N. J.

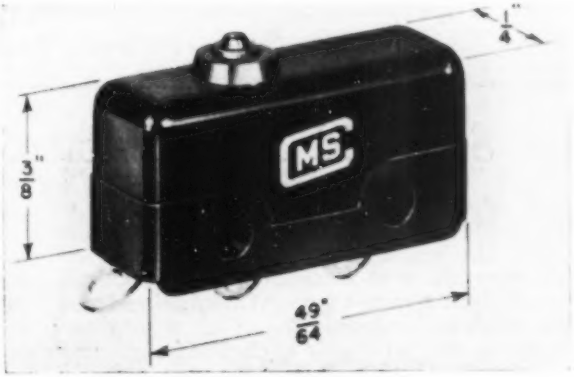
For more information circle No. 18 on Reader Service Card

Sensitive Switch Saves Space in Tight Applications

This new miniature plastic cased switch measures 49/64 by $\frac{3}{8}$ by $\frac{1}{4}$ in. It is offered for applications where space or weight are factors. A pin plunger actuator is used with a circuit arrangement single pole, double throw. Terminals are solder lug type.

Required operating force is 7 oz, maximum, with a release force of 1 oz, maximum. Movement differential is 0.030 in., maximum, with a pretravel of 0.008 in., maximum, and overtravel of 0.005 in., maximum. Electrical capacity tests indicate a rating of 5 amps, 115 to 230 v a-c, and 2 amps, 28 v d-c.

The above characteristics are listed as tentative by the manufacturer. Applications are possible for cam, lever, pulley or direct pressure actuation in a variety of mounting setups.



Micro Switch, Freeport, Ill.

For more information circle No. 19 on Reader Service Card

New Resistors Sealed Against Corrosion

These new resistors are coated with a vitreous enamel designed to withstand thermo-shock and corrosion by air, humidity or salt water. The wire terminals are a special alloy, and are spot welded to the resistor body. Between 5 and 200 watts rating, 12 resistors are available in standard sizes. In this range, 11 non-standard units are also available.

Adjustable resistors are available in the same sizes with a choice of 3 contact bands. A straight, narrow slot along one side of the unit is left free of enamel to expose a small arc of each turn of wire for contact. The under-side of each turn is firmly imbedded in enamel.

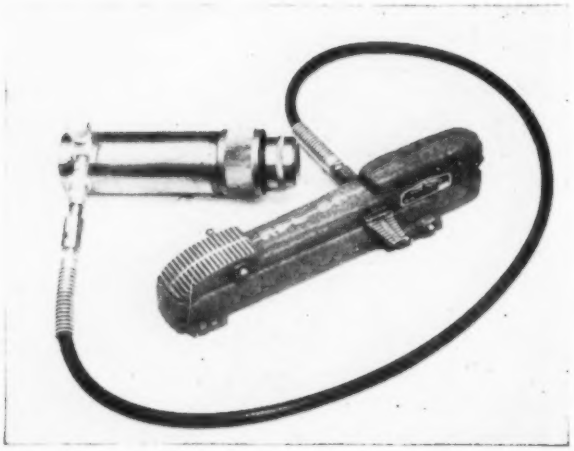
Twelve standard resistor terminals are available together with ferrule terminal resistors. The alloy ferrules are forced over the ends of the tube before enameling. Ends are left open for ventilation. Other resistors are furnished with aluminum thru-bars to distribute heat.

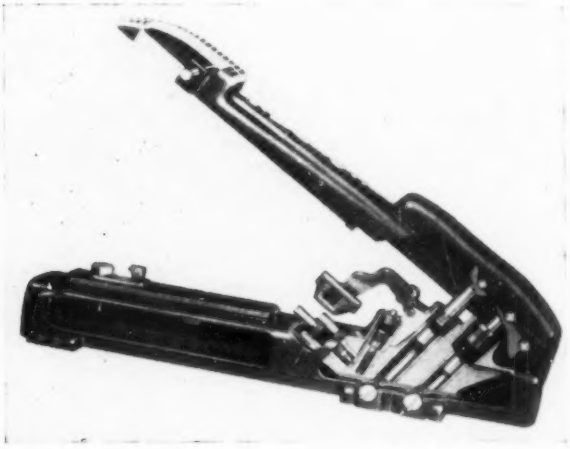
Harduick-Hindle, Inc., Newark 5, N. J.

For more information circle No. 20 on Reader Service Card

CONTINUED ON PAGE 178

Foot Operated Jack Develops 20 Tons Pressure





This foot operated hydraulic jack can develop up to 20 tons pressure. Both of the operator's hands are left free to do the work normally requiring an assistant. Both the pumping and control operations are under foot control at all times.

This new hydraulic jack has two speeds. A patented selector valve allows the operator to choose the right speed and capacity to suit the occasion. With the selector valve in the "out" position, the foot pedal will force the ram out quickly until the work is contacted. The unit then changes automatically from high to low speed to take advantage of the full capacity of the ram. For light work the selector valve can be set to the "in" position and the jack will operate at high speed constantly.

All working parts are made of high grade, heat treated, polished and ground steel. Bulky parts are of cast aluminum alloy. This extensive use of aluminum brings the total weight of the jack down to 10 lbs., including oil. The unit has $\frac{3}{8}$ in. male pipe thread fittings with a spring at each end. The finish is dark green crinkle, or such other as requested by the user.

Wihtol Industries, Lewis St., Eatontown, N. J.

For more information circle No. 21 on Reader Service Card

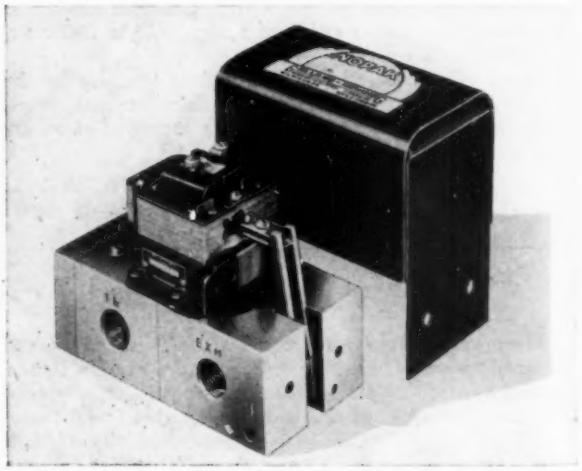
Solenoid Trips Pilot to Actuate Valve

A solenoid-actuated pilot is featured in this valve as a means of avoiding direct pull of the solenoid on the sealing mechanism. Before the solenoid is energized, line pressure is always on the same cylinder port, with the other cylinder port open to exhaust. The cycle is reversed when the solenoid is energized.

The 3-piece valve body is machined from drawn aluminum and is easily dismantled. The continuous duty solenoid is replaceable and is claimed by the manufacturer to be capable of efficient operation when completely submerged in oil, with no deleterious after-effects. The sealing mechanism consists of a valve ring and Neoprene O-rings in which the chrome-plated control valve floats. This aspect of the mechanism is designed to minimize lubrication requirements.

With a pull of 3 lb, the unit takes 0.96 amp at 220 volts. Air pressures of from 40 to 250 psi can be handled with the valve mounted in any position. The design allows for either continuous energization in one position, or long run, high speed operation. Weight is $5\frac{3}{4}$ lb and dimensions are $5\frac{7}{8}$ x 3 x $5\frac{1}{2}$ in. In addition to the model illustrated, a sub-plate mounted unit is available at extra cost.

Galland-Henning Mfg. Co., Milwaukee 15, Wis.



INLET AND EXHAUST PORTS are shown in this view of the unit with the cover removed. The operating solenoid and electrical connections are on top of the valve body. Operation is not affected by the position the valve is mounted in.

For more information circle No. 22 on Reader Service Card

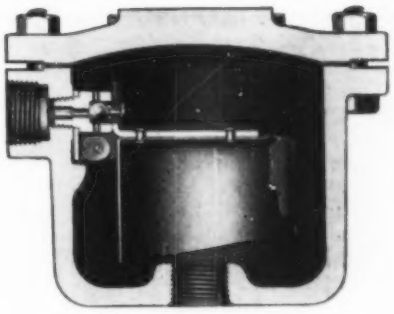
CONTINUED ON PAGE 180

When it's time to specify piping . . .
You save time by specifying CRANE

The reason is simple enough. Crane offers the world's most complete line of quality piping equipment. Everything you need for your design is carefully arranged and cross indexed in one catalog. You never need wade through pages to find what you're looking for. If it's piping, it's in your Crane Catalog . . . and it's easy to find.

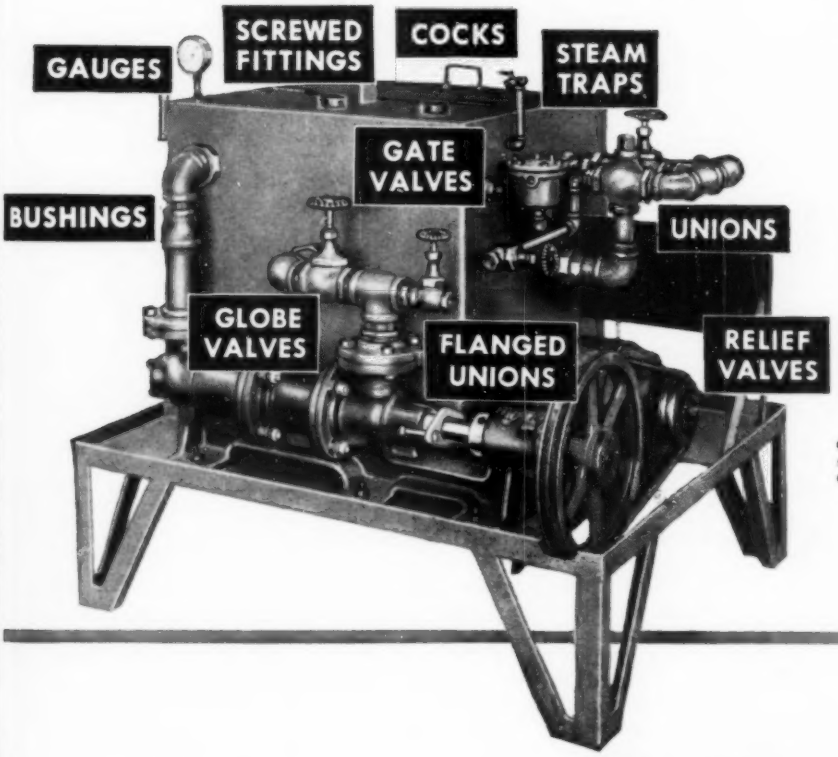
Working with Crane as your one source of supply offers other advantages, too. In your plant, piping assembly operations go smoother. Ordering and storekeeping are simplified; replacements in the field are easy to get. Most important, your product acquires added value because it is Crane equipped. Machinery and equipment buyers know that Crane Quality means high quality.

CRANE CO., 836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas



FOR STEAM HEATED or steam operated machinery, Crane recommends its line of Inverted Open Float Steam Traps. Small and compact, but with high discharge capacities, these traps have only one moving part. They work automatically, require virtually no maintenance, save fuel while keeping steam lines hot and dry. Easy to install. Made for steam pressures up to 300 pounds. See your No. 49 Crane Catalog.

EVERYTHING IN PIPING FOR YOUR DESIGN
. . . FROM ONE COMPLETE LINE . . . CRANE



Circulating unit, Poro-Seal casting sealer system by Timber Products Co., Chicago, Illinois

EVERYTHING FOR EVERY PIPING SYSTEM

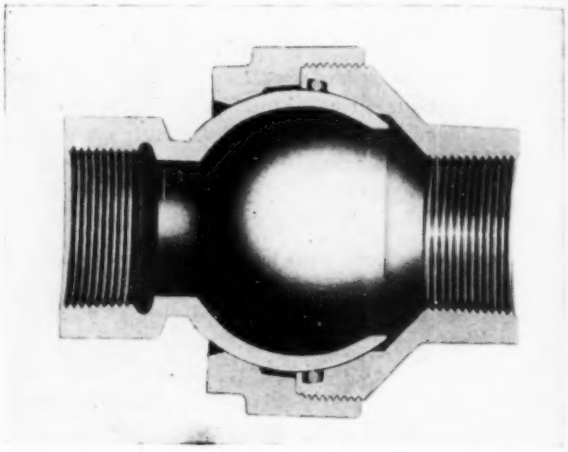
CRANE

VALVES • FITTINGS • PIPE • PLUMBING AND HEATING

"O" Ring Swivel Joint Has 40 Deg Angular Movement

Using an "O" ring seal, this swivel joint is constructed to give 360 deg swivel action and 40 deg angular movement. A union connection is employed and there is no packing ring to tighten. Standard "O" rings are recommended for oil, gas, air, water and steam (up to 350 F). For other services the manufacturer should be consulted. The fitting body is of bronze with chrome finish on the ball. Joints are available for $\frac{3}{8}$, $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2 and 4 in. pipe. All sizes have female threaded connections except the $\frac{3}{8}$ in. which is furnished with male thread on the ball. Although the new joint has only recently gone into production, it has been extensively tested by the manufacturer during the past year. The overall length of the fitting varies from $1\frac{3}{4}$ in. in the $\frac{3}{8}$ in. swivel to $8\frac{3}{8}$ in. in the 4 in. swivel. Variation in OD is from $2\frac{7}{16}$ to $9\frac{3}{4}$ inches. Angular adjustments are made by loosening the female member and setting the fitting to the required position. Union is then re-tightened.

John G. Bell Co., 712 E. 6th St., Los Angeles, Calif.



For more information circle No. 23 on Reader Service Card

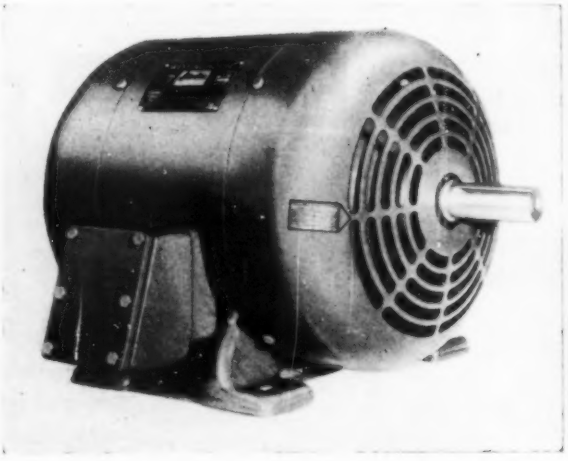
Special Motors Used in Corrosive Atmospheres

This new addition to the manufacturer's line of motors is designed for applications where corrosive fumes and liquids are encountered.

Frames, brackets, hoods and other exposed parts are alkali-cleaned, hot-water rinsed, then rinsed in chromic acid spray. After drying, they are sprayed with phenolic-alkyd type enamel and baked. Additional protection is provided by a coat of gray enamel and two to four baked dips of thermoset varnish, followed by a final coat of gray lacquer.

These motors use bronze split-hub, clamp-type blowers for corrosion resistance. Rotating neoprene slingers on the shafts between rear brackets and hoods are used to prevent the entrance of dirt or liquids into the bearing housings. Stator windings are double-dipped and baked in thermoset varnish. All hardware is dipped in slushing compound prior to assembly. The gasketed conduit box can be rotated to meet installation requirements.

Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh 30, Pa.



For more information circle No. 24 on Reader Service Card

Glass Throws Heat From Electrically Conducting Skin

This glass material is the result of research by the manufacturer in the field of electrically conducting coatings for glass. The new glass shows lower electrical resistance than was previously obtained, and is more stable and suitable for power dissipation applications. Working temperatures of 660 F are possible.

The base material is "Pyrex" brand borosilicate glass. A metallic oxide film, 16 millionths of an inch thick, is applied to the glass at high temperature. The electrically conducting skin is generally transparent and either colorless or tinted in various shades of blue. It is applied to the base in uniform or non-uniform coats, as the application requires.

The uncoated side of the glass radiates approximately twice as much heat as the coated side since the electrically conducting skin itself acts as a metallic reflector. Electrical resistivity can be varied over a wide range during manufacture. The glass has good corrosion resistance in the absence of reducing agents. Washing with ordinary cleansers has no ill effects, although abrasives should be avoided because of the thinness of the oxide surface coating.

Corning Glass Works, Corning, N. Y.

For more information circle No. 25 on Reader Service Card

CONTINUED ON PAGE 182

New Townsend Tufflok Nut Is Tougher Three Ways To Give You Tighter Grip, Greater Safety, With Economy

You get a tighter grip, greater safety and economy with the new Townsend Tufflok nut. It gives you more service at less cost. The exclusive Tufflok design*, plus the materials in the insert and nut body combine to give you the toughest lock nut yet produced for any use where nuts must stay put under a variety of adverse conditions. Here are the New Exclusive Features of the Townsend Tufflok Nut:

1. *Tough hexagon insert*—won't turn in its seat, gives you positive grip on the bolt at all times. Specially treated insert resists moisture, oil and drying out. Special inserts where special applications are required.
2. *Tough, one piece cold forged nut* has exclusive petal design to assure positive insert staking.
3. Tough threads *cut in cold forged steel* are stronger, spin on easier, resist galling, speed up application and also afford more reuse.

The quality, efficiency, and safety with economy, you get in the new Townsend Tufflok nut is made possible by the skill and experience gained by The Townsend Company as the oldest manufacturer of small cold formed fasteners in the United States. This know-how combined with the background of The Nylok Corporation in producing millions of lock nuts gives you the advantage of a reliable source for your lock nut requirements.

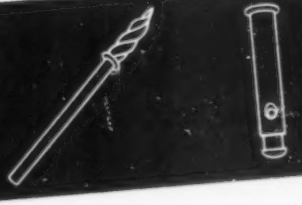
The new Townsend Tufflok nut with exclusive hexagonal treated insert and special cold forged body is available in machine screw sizes No. 4 through 3/8", cadmium or zinc plated. This line will be increased in the near future.

For longer service with greater safety and economy specify Townsend Tufflok Nuts. Write today for samples and complete information.

THE TOUGHEST LOCK NUT EVER PRODUCED

*Licensed under The Nylok Corporation patents. Tufflok is a trademark of the Townsend Company.

Call or write today to:



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COMPANY — ESTABLISHED 1816

New Brighton, Pa.

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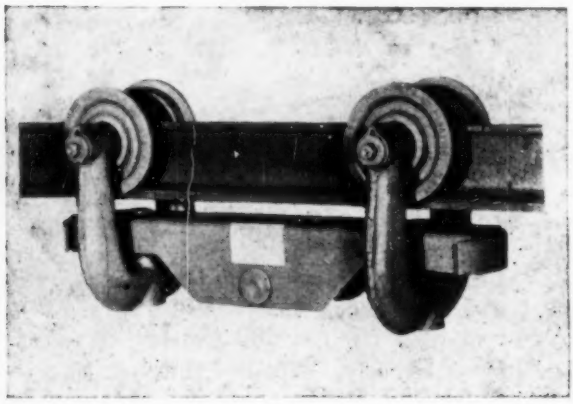
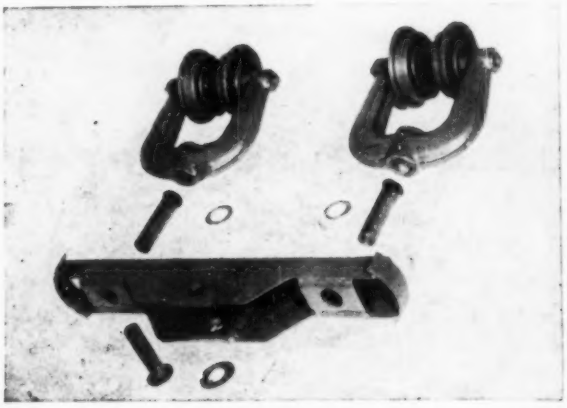
Tramrail Trolley Cuts Friction



THE TROLLEY YOKE swivels freely at the kingpins to prevent binding of the wheel flanges on curves. The four wheel unit with a 16 in. wheelbase is standard, but heavy duty, eight wheel trolleys and 36 in. wheelbase trolleys are also sold. The use of channel-shape, steel plate load bars cuts the weight of the trolley for the same load capacity. Applications are expected in tramrail systems, transfer bridges, and tramrail cranes. Alloy steel rails are furnished.



A REDUCTION IN RUNNING DRAWBAR PULL of 10 lb per ton is claimed for these tramrail trolleys. Wheels are chilled cast iron, 4½ in. tread diameter, with straight flanges and pressure-lubricated, anti-friction bearings. Treads are slightly crowned to protect track edges. The trolley yoke is a modified tube design, made from two steel stampings, welded back to back. Electric, pneumatic, or manual hoists are used.

The Forker Corp., 2061 Random Rd., Cleveland 6, Ohio

For more information circle No. 26 on Reader Service Card

Adjustable V-Belt Pulley Locks Solid

This adjustable diameter V-Belt sheave utilizes a tapered shaft bushing and a tapered sleeve to rigidly lock into a single "solid" sheave. The new pulley is designed to eliminate vibration, noise, and metal peening through a positive assembly in which no clearances are left between parts when the unit is locked and operating.

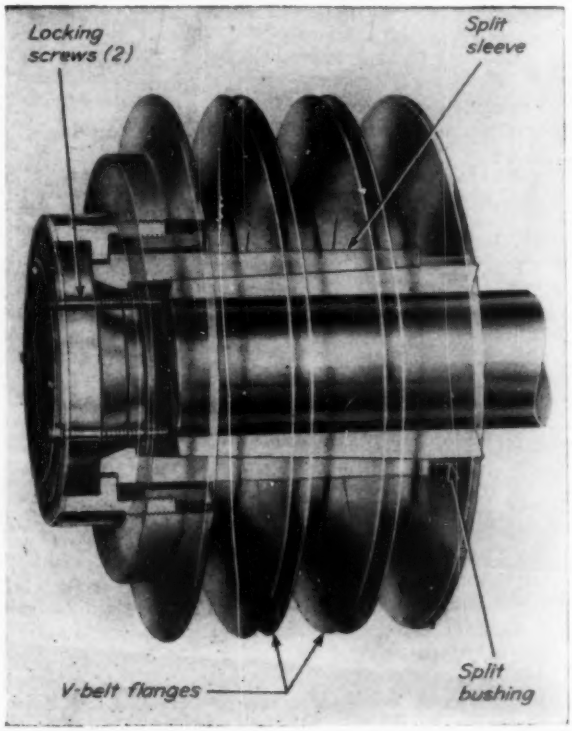
The split shaft bushing is tapered to adopt the sheave to undersize or oversize shafts. Quick breakaway in dismounting and positive clamping action on the shaft are also claimed. Locking action is accomplished by the two locking screws shown in the illustration.

The split-taper sleeve provides the locking force to hold the flanges to the hub. When the bushing is pulled in tight to lock it on the shaft, the wedging action expands the taper sleeve against the flanges, making the entire unit a "solid" sheave.

With the unit loosened, pitch diameter adjustment is accomplished by turning the adjusting collar with a spanier wrench. This collar is connected by a RH thread to the outboard flange in each V-belt groove. The inside thread of the adjusting collar is LH, and ties to the inboard flange in each belt groove. Thus, turning the collar simultaneously moves all flanges to increase or decrease the pitch diameter of the sheave. V-belt alignment is maintained at all times.

The new double-taper, adjustable diameter is offered for severe drive conditions. It is available for most standard and a wide range of adjustable-diameter drives.

American Pulley Co., 4200 Wissahickon Ave., Phila. 29, Pa.



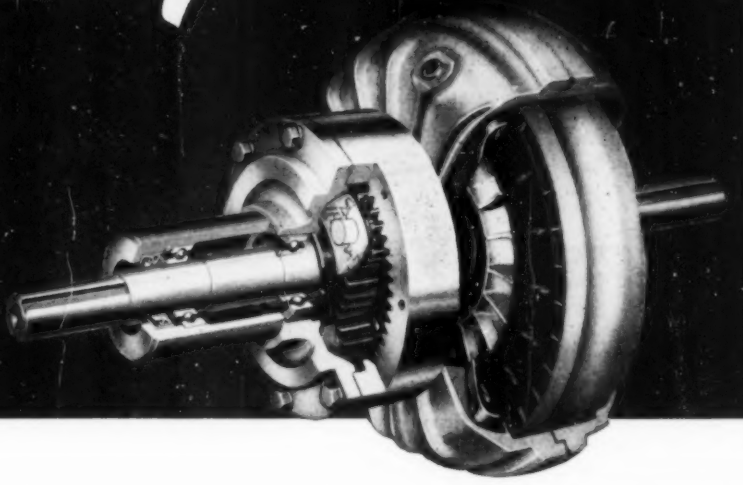
For more information circle No. 27 on Reader Service Card

CONTINUED ON PAGE 184

Twin Disc Announces the

Hydro-Wynd

for Constant Tension Wind-up



For winding applications in:

Textile Industries

Printing Processes

Paper-Making Machinery

. . . Wherever roll diameters vary and constant lineal speed and tension are required.

The Hydro-Wynd combines an hydraulic coupling with a planetary gearset to mastermind the delicate job of maintaining predetermined tension and speed on wind-up applications, *without constant adjustments*.

In order to maintain constant speed and constant tension on the material to be wound, the Hydro-Wynd automatically balances speed-torque requirements in the drive to the spool shaft—eliminates the need for constant manual control.

See your Twin Disc Dealer for full information about the new Hydro-Wynd for *your* winding application, whether it's wire, plastic, thread, paper or yarn. Currently available Hydro-Wynd units, singly or in compound, are capable of handling up to 7.5 horsepower.

Uniform tension held automatically throughout roll build-up—convenient operator control of tension over a wide speed range—high quality cloth—reduced safety hazard: that's the performance report on a Hydro-Wynd installed on a Morrison Tenter Frame in a large Southern textile finishing mill.

TWIN DISC
CLUTCHES AND HYDRAULIC DRIVES

Clutches & Hydraulic Drives

TWIN DISC CLUTCH COMPANY, Racine, Wisconsin • HYDRAULIC DIVISION, Rockford, Illinois

BRANCH OFFICES: CLEVELAND • DALLAS • LOS ANGELES • NEWARK • NEW ORLEANS • SEATTLE • TULSA

Time Delay Device Automatically Restarts Motors

This new motor control accessory, is designed for use with a separate motor starter and pushbutton station to provide automatic restarting of a motor after a momentary voltage fluctuation or power failure of a few seconds duration. If the power failure is prolonged more than a few seconds, the relay circuit "times out", disconnecting the motor from the line, thereby protecting operators and machinery from unexpected restarting of the motor upon restoration of power. Use of this time delay low voltage release device prevents needless shutdowns caused by momentary power failures.

Automatic restarting is assured if the voltage returns to 85 percent of normal within the time for which the device is set. It can be adjusted to give approximately 2 sec or 4 sec time delay. A feature of the design is that one device can be used with any number of pushbutton stations for operation of a motor starter from several remote locations.

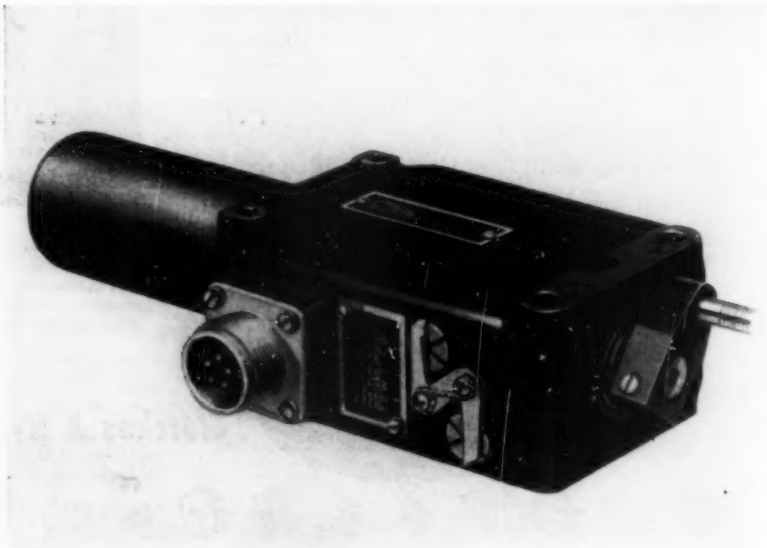
The new devices are available in NEMA Type I general purpose (sheet steel) enclosures or in NEMA Type VII explosion-proof (cast iron) enclosures for Class I Group D hazardous locations. They can be used with a suitable motor starter for control of ac motors rated up to 200 horsepower. NEMA Type I shown.

Square D Co., Industrial Controller Div., 4041 N. Richards St., Milwaukee, Wis.

For more information circle No. 28 on Reader Service Card

Rotary Actuator Operates A-C or D-C

This electric rotary actuator, operating on either low voltage d-c or 110 v a-c has been redesigned into a more compact unit weighing 2¼ lb. The standard gear ratio produces 350 in.-lb operating torque through 180 deg maximum rotation. Static capacity is stated as exceeding 1,500 in. lbs. This unit incorporates zero backlash output, a magnetic brake, built-in externally adjustable limit switches and potentiometer, and a radio noise filter. Accurate and sensitive positioning or electrical synchronizing controls are available. Provision for mechanical synchronizing in pairs is optional. Applications for the improved unit are expected in the aircraft industry on remote reading and positioning devices, where accurate rotation control is needed.



Airborne Accessories, 25 Montgomery St., Hillside 5, N. J.

For more information circle No. 29 on Reader Service Card

CONTINUED ON PAGE 180

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And a problem's got you down,
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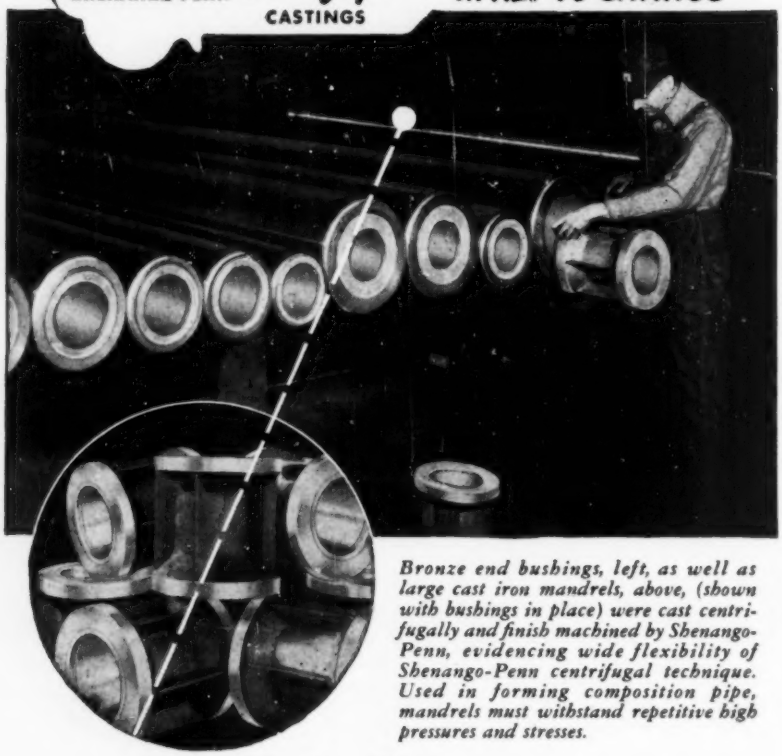
SHENANGO-PENN *Centrifugal* CASTINGS ... KEY TO SAVINGS



Bronze end bushings, left, as well as large cast iron mandrels, above, (shown with bushings in place) were cast centrifugally and finish machined by Shenango-Penn, evidencing wide flexibility of Shenango-Penn centrifugal technique. Used in forming composition pipe, mandrels must withstand repetitive high pressures and stresses.

For high pressures, high stresses . . .

IF you need rolls, or *any* symmetrical or annular parts requiring unusual strength, uniformity, wear resistance or freedom from porosity and defects, check with Shenango-Penn. These very qualities are inherent in the carefully controlled Shenango-Penn *centrifugal* casting process. You stand to save time and money . . . to avoid needless trouble.

Check also on Shenango-Penn's modern machining and finishing service. It combines complete facilities and years of specialized experience to meet your specifications with over-all precision . . . another time-and-money saver!

For free descriptive bulletins, for specific data on ferrous or nonferrous work, large or small, semi or finish machined, write to . . .

SHENANGO-PENN MOLD COMPANY
686 West Third Street Dover, Ohio
Executive Offices: Pittsburgh, Pa.

SHENANGO PENN

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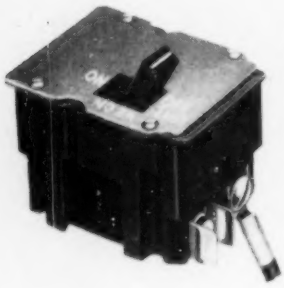
MONEL METAL · NI-RESIST · MEEHANITE® METAL

Two Pole Multi-Breaker Extends Circuits

This new 2-pole multi-breaker is offered to extend circuit arrangements on the manufacturer's standard load centers. These can now be extended to include up to a maximum of three double poles in combination with various single pole circuits for lighting loads. The new unit is a thermal-magnetic, common trip breaker having only one operating handle, for use with 220 v loads.



Square D Co., Detroit 11, Mich.

For more information circle No. 30 on Reader Service Card

New Resin Is Processed At 300 Deg F

Possessing high thermoplasticity, solubility and good processing characteristics at moderate temperatures, this new product introduces the properties of Geon polyvinyl chloride resin into another product range where heretofore certain material limitations have restricted its use. It can be extruded, calendered or molded in unplasticized form and at temperatures under 300 Fahrenheit.

Vinyl resins are unaffected by water, grease, oils, ozone, salts, alkalies, acids, oxidizing and reducing agents in fairly high concentrations and at relatively high temperatures. The chemical inertness of vinyls is claimed to be unequalled in rigid plastics.

The vinyls are also noninflammable. Other properties include high dielectric strength, good insulation properties, excellent impact resistance, and superior abrasion resistance.

Some applications in which the new resin is expected to find a ready market are phonograph records, rigid sheet and piping, and even protective coatings and adhesives. The heat stability of the new resin for long

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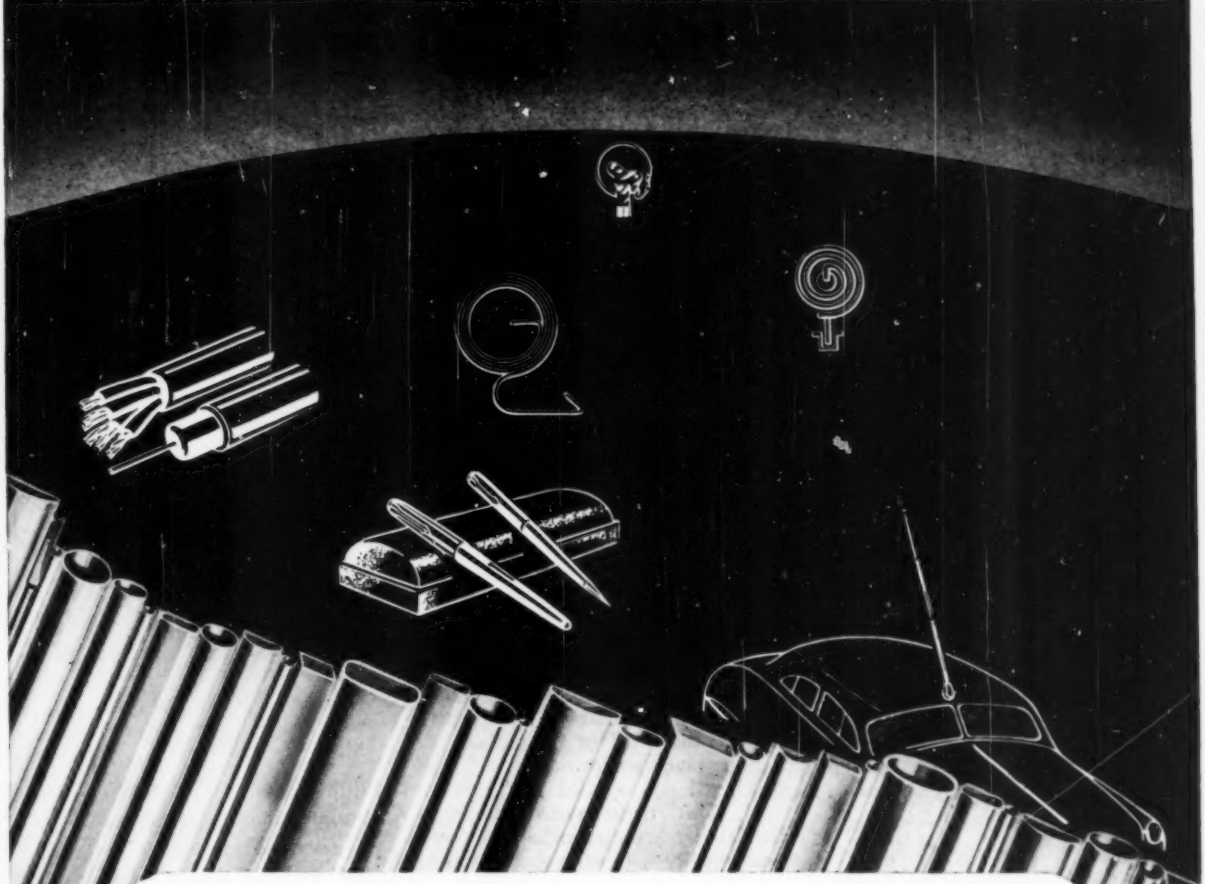

PRECISION TUBING INCREASES INSTRUMENT ACCURACY

Here are just a few of the many products where you'll find *Precision* tubing being used.

Designers are choosing *Precision* tubing because of its accurate I.D. and O.D.—reduced weight—suitability for painting and plating—increased strength and durability—mirror-like finish—and the fact that it is supplied in . . .

MANY SHAPES, SIZES, ALLOYS!

SHAPES: Round or rectangular, oval or square, and special shapes.

SIZES: 0.500" to 0.010" O.D.; wall thicknesses down to 0.0015".

ALLOYS: Available in most alloys, including aluminum, copper, brass, phosphor-bronze, nickel-silver, cupra-nickel, nickel, monel, Ni-Span-"C" and stainless steel.

Specify *Precision* when you design a new product or redesign an old one and small tubing has a job to do. You'll get tubing that's easily formed . . . readily fabricated wherever you want to use it.

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WHEN PRECISION COUNTS — COUNT ON PRECISION

PRECISION TUBE COMPANY, INC.

periods makes it possible, through proper compounding, to produce transparent molding, as well as calendering and extrusion compounds. Possessing good clarity, it can be used to produce clear, rigid sheet or piping. Low viscosity cements can also be formulated by dissolving the new resin in solvent mixtures of acetone and an aromatic component.

B. F. Goodrich Chemical Co., 324 Rose Bldg., Cleveland 15, Ohio

For more information circle No. 31
On Reader Service Card

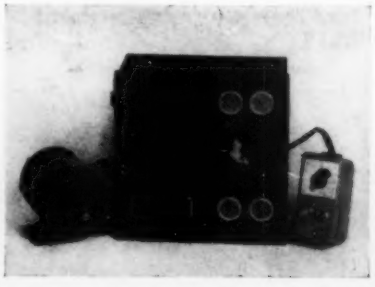
Thyratron Voltage Controls Fractional Hp Motors

This simplified thyratron type motor speed control system operates dc motors from the ac line. Shunt wound type 115 v motors of from one thousandth to one tenth hp may be controlled over a speed range of better than 50 to 1 with nearly constant speed versus torque regulation. A physically identical model is available for operation from the 220 v line to control dc motors of the shunt wound type up to one sixth hp. The speed range is the same for either unit.

Full wave vacuum tube rectified dc is filtered and applied to the motor field. This rectifier system eliminates the field weakening problem associated with disk type rectifier sources whose output voltage becomes lower with age. A thyratron controlled variable voltage is supplied the armature to vary motor speed from base speed downward. Feedback to provide a constant output voltage versus load results in regulation characteristics not achievable in many other control systems.

The power supply cabinet for this system is made as a separate unit and may be mounted at any convenient point removed from motor location, when desired. This cabinet measures 8 x 8 x 4 in. and may be wall mounted. Power supply chassis is removable.

The control station case which may be mounted near motor or near operator's other hand-type controls is



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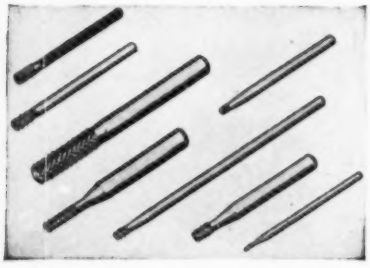

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Typical are mandrels or spindles for mounted grinding wheels, abrasive points, felt wheels. Shank diameters to .500", close tolerances, centerless ground if desired. Chuck ends rounded, no burrs. Sharp, clear uniform knurls. Concentric tapers. Mandrels accurately hand-straightened.

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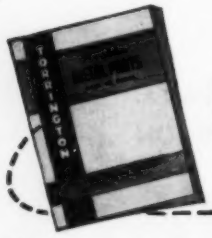

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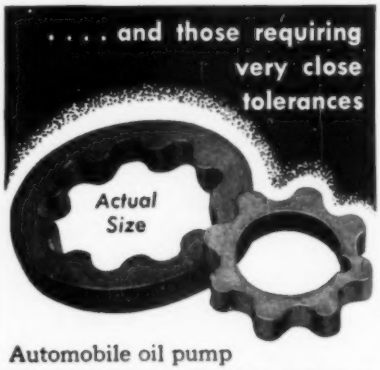

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EQUIPMENT

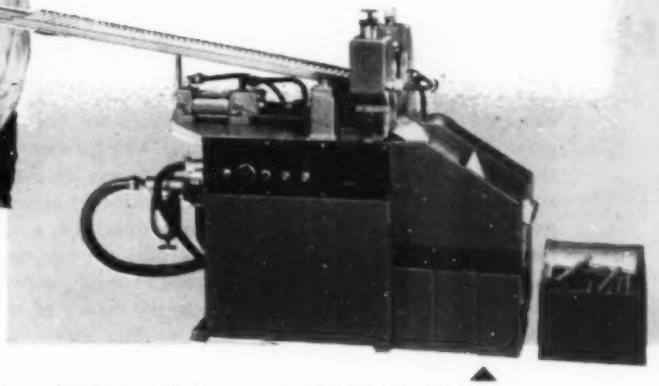
Through basic engineering developments, Brown & Sharpe custom-builds uniquely simple inspecting and sorting machines for precision parts. Machines of this description made by Brown & Sharpe have the advantages of simpler, sturdier construction; more stable adjustments; and easier manipulation of sensitivity.

This modern equipment can be designed and built to meet individual needs for:

1. *Manual loading and disposal*
2. *Manual loading and automatic disposal*
3. *Automatic loading and automatic disposal*

Why not turn over your problems of providing efficient gaging and sorting equipment to Brown & Sharpe? Send an outline of your requirements. Learn what Brown & Sharpe can offer in custom-engineered equipment. Brown & Sharpe Mfg. Co., Providence 1, R. I., U. S. A.

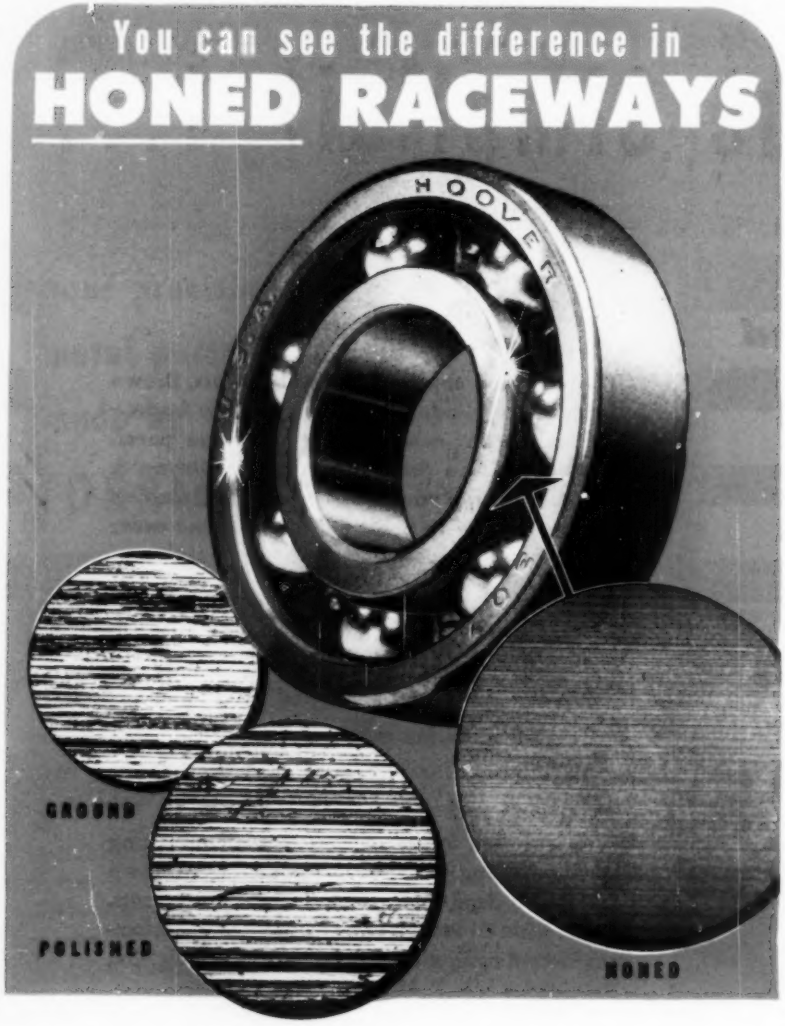
This single-motor, compact machine automatically gages and sorts antifriction bearing rolls. It rejects rolls above or below manufacturing tolerance and separates accepted rolls into 5 sized categories, in increments of .00002".



This machine gages and sorts straight sleeves—measuring for length as well as diameter at both ends. The sleeves are segregated into four categories. **1.** *Oversize and undersize in length regardless of diameter.* **2.** *Small in diameter at either or both ends.* **3.** *Large in diameter at either or both ends.* **4.** *Good sleeves within tolerance.*

The machine has a production rate of approximately 3000 per hour. The capacity is adjustable for different lengths and diameters. It is loaded manually with automatic disposal.

BROWN & SHARPE



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The photographs reproduced above are magnified one hundred times so you can see the difference between ground, polished and honed raceways. The process and the special machines for the honing operation are exclusive, patented, Hoover developments. Honing by Hoover goes far beyond grinding and polishing to achieve a surface that assures amazing quietness plus *90 per cent longer bearing life . . . 30 per cent greater load capacity.* That's why Hoover Ball Bearings are the choice of distinguished American manufacturers of fine machines and equipment.

The Hoover Engineering Manual will be mailed free to engineering and purchasing executives requesting a copy on their business letterhead.

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HOOVER BALL and BEARING CO.
Ann Arbor, Michigan

2 x 2 x 4⅛ in. long. The speed control potentiometer, pilot light and idle switch are contained in this control head. The idle switch allows the operator to stop motor and start again for preset speed without changing speed setting. Speed change is accomplished by turning a control potentiometer with a torque requirement of less than one in-oz.

Servo-Tek Products Co., 4 Godwin Ave., Paterson, N. J.

For more information circle No. 32 On Reader Service Card

Magnetic Starter Has Built-In Disconnect Switch

These combination magnetic starters are equipped with disconnect switches in the fusible or non-fusible type. The new motor starters are for industrial and commercial use where a magnetic full voltage starter coupled with disconnect means at starter location is preferred over separately mounted components.

Starters with fusible disconnect switches fulfill NEC requirements for motor branch circuit over-current protection, disconnecting means, motor running over-current protection and motor starter. Non-fusible starters meet these same requirements except for motor branch circuit protection. Components arranged in NEMA Type 1 General Purpose Enclosures are internally pre-wired and accessible.

Starters are available in four standard sizes to 50 hp, 3 hp, 550 v, 60 cy maximum. Standard operating coils can be supplied for 110, 220, 440 and 550 v service on frequencies of 25, 50 or 60 cycles. All standard starters are equipped with manually reset overloads. On special order, automatic reset overloads, local control "start-stop" pushbottons or "hand-off-auto" selector switches can be furnished.

Ward Leonard Electric Co., Mount Vernon, N. Y.

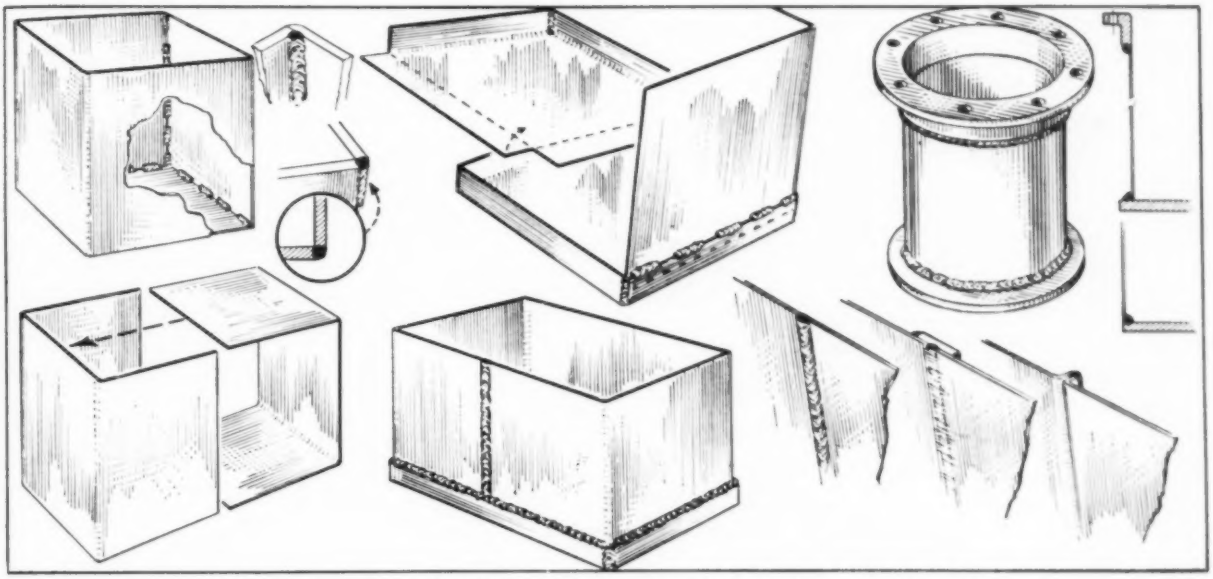
For more information circle No. 33 On Reader Service Card

Composition Disk Seals New Valves

This new line of globe, angle and check valves has been designed for liquid petroleum gas service. It has been tested and approved by the Underwriter's Laboratories, Inc. for use on LP gas up to 250 psi.

The disk is of synthetic composition for use with petroleum products. Soft enough for tight seating, it is de-

Looking for Ways to Simplify Design and Cut Costs of Machine Parts?

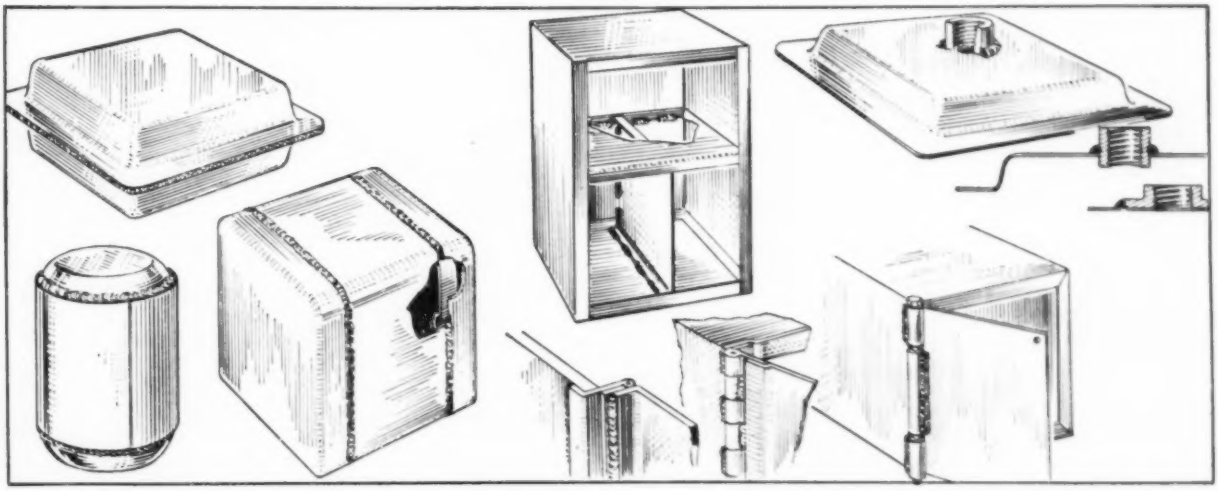


Containers and covers for machinery built simpler, yet stronger, lighter and at lower cost with arc welding.

HERE are some thought starters on how typical machinery parts like containers and covers can be built stronger, lighter and at lower cost with arc welding. Shop fabricating methods are also greatly simplified since component parts are sheared and formed from sheet steel, then held in simple clamp type fixtures and arc welded.

Through the use of arc welded design, it becomes possible to eliminate many machining operations formerly needed with other methods. With welded construction, less material is required, thus reducing the weight of operating parts.

Arc welding produces solid, one-piece construction to give dependable, trouble-free service. It eliminates all possibilities for loosening of joints as in riveted design.



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by 1/32" increments up to 5"
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THE BOONTON MOLDING COMPANY

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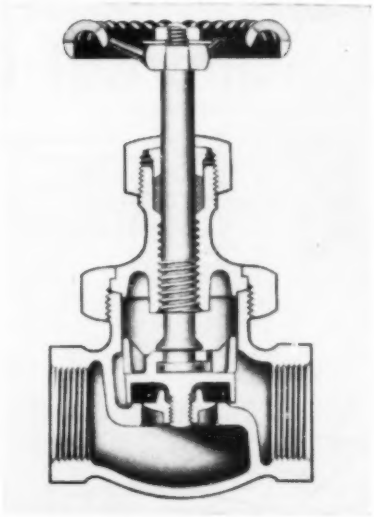


signed to have the stiffness and resilience to withstand hard wear. The disk is held firmly in place and reinforced against strains and distortion by the retaining nut with its wedge-shaped collar. The disk is also cemented into the holder as an added precaution. Sizes from ¼ to 2 inches.

The packing used in these valves is one-piece molded asbestos, specially suited for LP gas and other volatile liquid services. The packing box is featured by ample capacity to ensure long-lasting seal.

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.

For more information circle No. 34 On Reader Service Card

Photoelectric Control Features Forward and Reverse Circuits

For versatility in safety applications, this photoelectric control is supplied with forward and reverse circuits so that tube replacement is indicated by either an energized or de-energized relay. It is available with a phototube integral with the control or located in a separate housing.

The double-pole, double-throw relay operates from 115 and 230 v supply. Designed for high-speed operation, the relay is actuated in 1/20th of a second by L 30 and 40 AD 1 light sources at 10 ft and by L 60 light source at 20 ft.

The maximum rating is 10 amps, 115 v, ac, 5 amps, 230 v, ac, non-inductive, ½ horsepower.

Photoswitch Inc., 77 Broadway, Cambridge 42, Mass.

For more information circle No. 35 On Reader Service Card

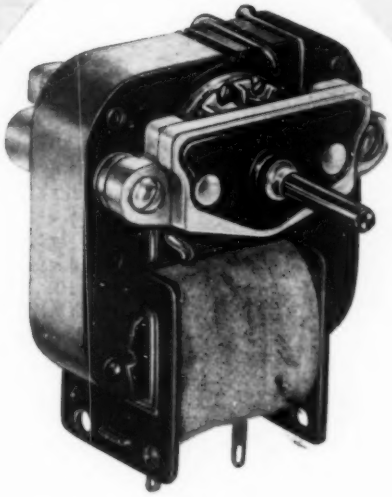
RAYTHEON

Fractional hp

MOTORS

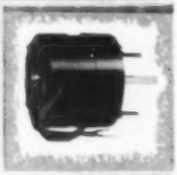
concentrated power

"Count on Raytheon to run it." That's what design engineers are saying. They're the men who appreciate the Creative Craftsmanship that goes into Raytheon fractional hp motors. Concentrated power in a small package—dependable performance at the shaft—those are the Key words in Raytheon design and engineering. When you want to *run* things, FANS, BLOWERS, HEATING EQUIPMENT, appliances or what have you—count on Raytheon motors to do the job. Call on your Raytheon motor representative for consultation on your specific application.

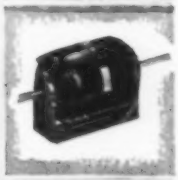


Type 230 Shaded 2-Pole Motor. For continuous duty without fan cooling. 1/200 to 1/50 hp at 3200 rpm. Flat Speed Torque Curve and High Starting and Pull Up Torque are characteristic of all Type 230 Raytheon motors. Efficiency is almost double the value ordinarily obtained in shaded two-pole motors of this type. Write for Data Bulletin 1000.

RAYTHEON TYPE 350 SHADED 2-POLE, 3000 rpm MOTOR.



RAYTHEON TYPE 330-S 4-POLE, 1/10 to 1/50 hp, 1550 rpm MOTOR.



RAYTHEON TYPE 470 SHADED 6-POLE, 1050 rpm INDUCTION MOTOR.

RUSSELL ELECTRIC COMPANY

MOTOR DIVISION OF RAYTHEON MANUFACTURING CO.

4501 So. Western Boulevard Dept. F-22 Chicago 9, Illinois

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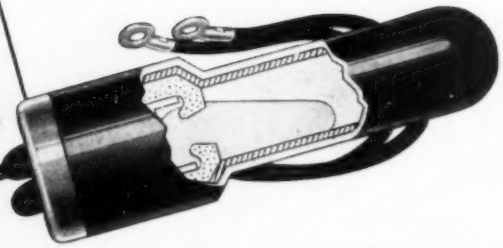

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OUR READERS SAY

Aircraft Production Design

To the Editor:

You will, no doubt, be interested in an article I ran across in the February issue of the *Engineering Experiment Station News*. Authored by Professor Frank Mallett of Ohio State University, the article, "Aircraft Production Design", said, in reference to editorial coverage of production design:

"A literature survey for the aeronautical field shows again the remarkable lack of emphasis on production design. There are no books that deal with the subject in its proper sense. A few pamphlets have been written on certain special topics, published usually as a customer service by such companies as the Aluminum Company of America and the International Nickel Company, and are concerned more with the manufacturing processes than with production design.

"In the periodical literature, such as the *Journal of the Aeronautical Sciences* production design is virtually unheard of. It is natural that at this level the other phases of design, along with their background subjects such as dynamics, fluid mechanics and elasticity, should dominate. However, even at this level there are production design problems needing treatment, as has already been mentioned.

"In the commercial periodical field, some attention has been paid to production design. If any one magazine should be singled out for its coverage of this subject, it is PRODUCT ENGINEERING."

—JOHN KENT
Washington, D. C.

Ed—Needless to say, we are happy to hear about Professor Mallett's statements.

Three More Gear Factors

To the Editor:

The article by Mr. Davis M. Wood in your March 1950 issue gives an interesting approach to the problem of "Determining Gear Tooth Surface Durability". His method, like Buckingham's, takes the realistic viewpoint that gear capacity is determined by hardness of material, required life (revolutions of pinion), and accuracy

of the gearing. Many other gear formulas in widespread use are deficient in neglecting one or more of these items.

Before commenting further, I believe the formula at the bottom of column three, page 104, should contain a second "plus" sign in the denominator to read as follows:

$$W_d = \frac{0.05\,(C + W)}{0.05 + \sqrt{C + W}} + W$$

There are three additional factors that should be considered in establishing a gear rating:

(1) What is the nature of the loading on the gear train? It is a well established fact that gears between a reciprocating engine and an air compressor will carry much less load than those between an electric motor and a generator.

(2) What margin should be allowed for safety? Where human life is at stake or valuable power plant equipment would be idled, gear failures cannot be tolerated. In many tools and appliances, gears can be designed with the expectation that they will wear and require replacement.

(3) What materials should be chosen? Some 200-Brinell gears may operate better than those with a hardness of 400-Brinell. Case depth, grain size, residual stresses, alloy content, all have a profound effect on whether or not a gear will perform in accordance with its hardness. The slope of stress-life curves varies considerably for different materials.

Comparing Wood's formula with Buckingham's, it is apparent that each plots curves that soon tend to be asymototic to a certain line. As the pitch line velocity approaches infinity, the ratio of dynamic load to nominal load becomes

$$\frac{W'_d}{W'} = \frac{C + 2W'}{W'} \quad \text{(Wood)}$$

and

$$\frac{W_d}{W} = \frac{FC + 2W}{W} \quad \text{(Buckingham)}$$

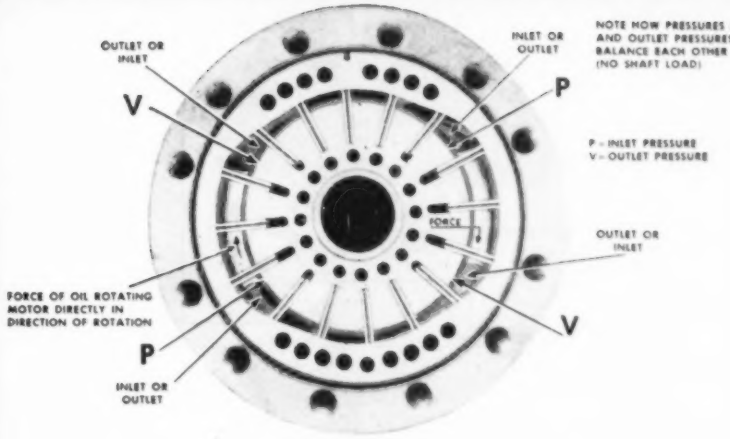
where W' = lb per in. of face
W = total load, lb
F = face width, in.
W_d = equivalent load, lb
C = constant (dependent on tooth errors and elasticity of material)

If values for this ratio are calculated for different conditions of tooth loading and face width, both Wood's and Buckingham's formulas approach the same asymototic value as the pitch-line velocity approaches infinity.

The principal difference in the two formulas is that Wood's approaches the asymotote more rapidly. The table below shows this general tendency, assuming a value of 1,000 lb per inch

Save Money! Save Space!

Dudco VANE-TYPE MOTORS



Dudco Vane-Type Motors operate by direct force of the fluid against the vanes. The fluid enters through ports which are diametrically opposed, to balance shaft loads, and discharges in the same manner. Notes included with the above figure relate to fluid motor construction. Pump operation is similar, with the dual vanes bearing radially outward with positive forces which, while adequate for pressure sealing, are balanced hydraulically to eliminate undesirable wear producing thrust against the ring.

CHECK THESE FEATURES

- DUDCO MOTORS operate down as low as 10 or 15 RPM at high torques often eliminating the necessity for gear reduction units
- Starting torque is over 93% of theoretical torque
- Torque ratings from 9 lb.-in. to 550 lb.-in. per 100 PSI available
- Quiet operating even at 3600 RPM
- Smaller size for ease of application
- Overall mechanical efficiency 85% at 1200 RPM, 77% at 100 RPM after long use
- 120 HP available at 800 RPM
- Hydrauliically balanced for long life—without any mechanical means for holding vanes out against the stator ring
- Rugged reversible service is common application

CHECK THESE USES

- Lumber (Resaws, slitters, conveyors, carriage feed works).
- Cannery (Box dumpers, fruit conveyors).
- Machine Tools (Thread tapping, lapping, indexing, bending machines, etc.).
- Chemical (Centrifuge, mixers, agitators, screw conveyors).
- Mining Equipment (Traction, Shoveling).
- Trucks (Hose reeling, conveyors).
- Railroad Work Equipment.
- Drilling Rigs (Rotary table, cathead, winch)
- And many more

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STAINLESS STEEL FASTENERS

of face and 10 in. for the face width.

Speed, fpm	Dynamic Load Ratio (W_d/W)			
	$C = 415$, $e = 2.5^{-4}$		$C = 1{,}660$, $e = 0.001$	
	Wood	B'k'ham	Wood	B'k'ham
1,000	1.81	1.42	2.31	1.62
2,000	2.03	1.65	2.75	2.01
4,000	2.19	1.89	3.12	2.47
10,000	2.32	2.14	3.41	3.00
20,000	2.36	2.27	3.53	3.29

Formulas such as those of Wood and Buckingham can only be justified if the gears are rigidly connected to stiff shafts having considerable inertia. Buckingham has developed more complex formulas that permit shaft stiffnesses and inertias of connected apparatus to be evaluated. This makes it possible to calculate a more true dynamic load.

It is interesting to note that Wood would not rate a high speed[1] gear set on a turbine-driven ship up to present practice. These gears with ten or more inches of face width and pitch-line speeds up to 20,000 ft per min will carry, for several billion cycles, loads that are about twice what Wood's formula would give. And, these gears have a high margin of safety.

Tests recently conducted show conclusively that certain aircraft gas turbine gearing with errors in the order of 0.00025 can operate with a dynamic load ratio as low as 1.25. Pitch-line speeds were 3,000 to 7,000 ft per min. Wood's formula would give a ratio of about 2.25.

In some cases, gears will fail with little or no applied load. No known formula will predict their performance. The only solution is to find a "formula" that will enable the parts to be manufactured more accurately.

In general, Wood's formula is conservative for high precision gears with smooth sources of power. It is an improvement over some formulas in common use. Several factors are not covered; such as, tip modification for bending[2], speed required to develop an oil film, sources of power, stiffness and inertia of connected apparatus, margin of safety and materials.

—D. W. DUDLEY
Gear Engineering Div.,
General Electric Co.

REFERENCES:

1. "Modern Marine Gears" by J. J. Zrodowski and D. W. Dudley, *Transactions of Society of Naval Architects and Marine Engineers,* 1950.

2. "Modification of Gear Tooth

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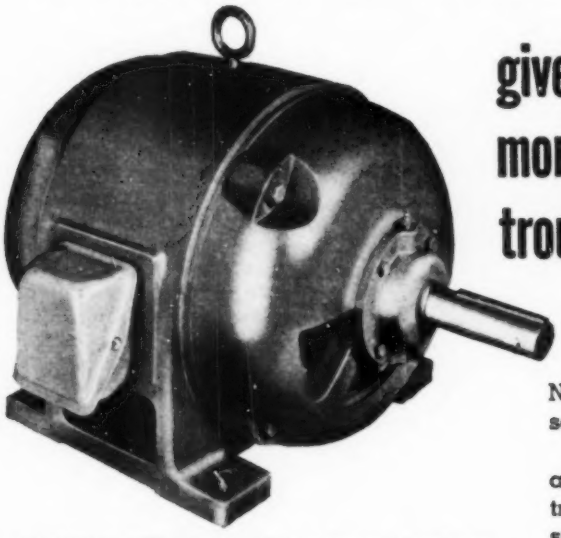
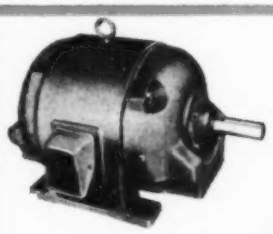
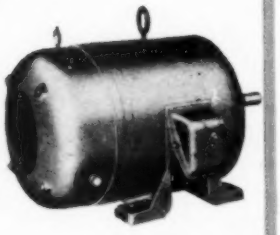


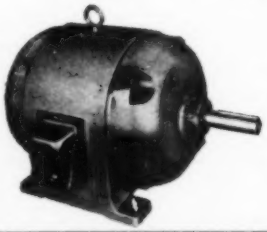
E. D. DRIP PROOF INDUSTRIAL MOTOR. For use under ordinary industrial conditions not requiring protection from splashing liquids or from atmosphere laden with dirt or metal chips.



SPLASH PROOF
For installation where the motor is subjected to splashing liquids or hosing down for cleaning.



TOTALLY ENCLOSED
(Fan Cooled)
For use in dirt-laden atmospheres, especially where the installation requires a motor of compact dimensions.



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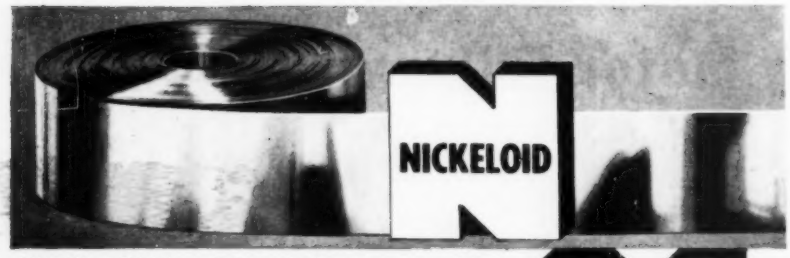

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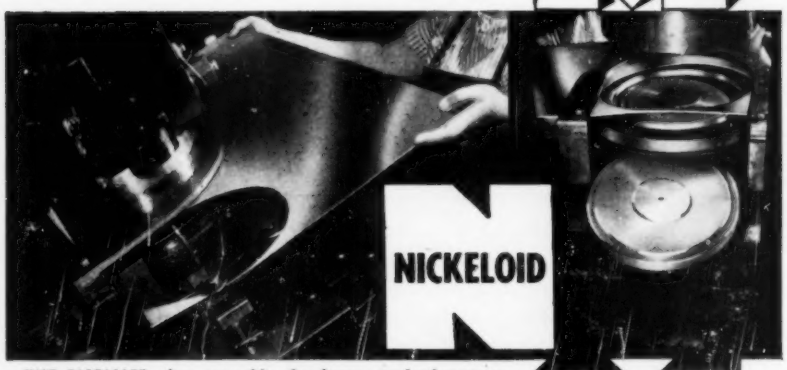

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Profiles" by D. W. Dudley, PRODUCT ENGINEERING, September 1949.

A Problem for Someone

To the Editor:

The average automobile engine operates at efficiencies as high as 25 percent. To obtain this degree of efficiency, the engine must be operated at high brake mean effective pressures with the throttle about three-fourths open. With a surplus of power available and our present-day transmissions, we operate at low brake mean effective pressures under normal driving conditions. Because of the high rpm of the engine and the high losses accompanying throttled operation, engine efficiency is about 13 percent at 30 mph. An engine will develop its highest efficiency when the brake mean effective pressure is in the neighborhood of 80 psi. At 30 mph, the actual brake mean effective pressure is more like 20 psi, which means the engine is being throttled considerably.

We are now operating our engines at high speed and low brake mean effective pressures. By operating at low rpm and high brake mean effective pressures, we can develop the same horsepower, and can do so much more efficiently. Consequently, I propose that someone undertake to invent and develop an automatic transmission that would allow the engine to operate under the conditions mentioned above. Obviously, such a project would have to be undertaken by the major manufacturers who have the necessary facilities and funds.

At Illinois University, we have conducted tests on a 1949-model, popularly-priced car. With the standard overall drive ratio between the engine and rear wheels in high gear, the following engine speeds and gasoline mileages were obtained:

Speed, mph	Engine rpm	Miles/gal
20	1,017	19.0
30	1,525	21.5
40	2,035	22.5
50	2,540	20.0
60	3,050	17.0
70	3,560	14.0

By using the optimum overall ratio between the engine and rear wheels as shown below, a great improvement can be shown in gasoline mileage. Note that optimum ratios are given, and that they vary with road speed. Note also that the lowest operating rpm of the engine is not less than 500. This has been selected as the lowest

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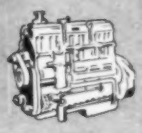

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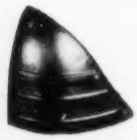
Acid Resistant	Cemented	Decorated or Plain
Excellent Dielectrically	Buffed—Polished	Bright or Somber Colors



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K. B. Plastics, Inc. 1817 So. 1st St., Yakima

WISCONSIN
Midland Plastics Inc., 227 N. Water St., Milwaukee 2

The United States Rubber Company at 2638 North Pulaski Road, Chicago, Illinois, has complete Engineering, Designing, and Styling Departments to assist fabricators on the technique to employ, and in the art of fabricating, most efficiently with ROYALITE.

engine speed consistent with smooth and regular operation.

Speed, mph	Engine rpm	Engine-wheel ratio	Miles per gal
20	507	2.05	31
30	520	1.40	36
40	595	1.20	36
50	865	1.40	31
60	1,187	1.60	26
70	1,558	1.80	20

At the top speed of the car, the engine-to-wheel-ratio would be the same as that of the current standard car. At 10 mph, it would also be the same as that of the standard car.

The trick is to invent a transmission that would have the characteristics shown above, and would do so with the same efficiency as that of our present hand-shift transmissions.

In order that the car have the same acceleration and hill-climbing ability as that of our standard cars, an automatic "kick down" would have to be provided. Such a unit would operate in a manner similar to existing overdrives and automatic transmissions. Our present engines would have to be modified so that they could operate continuously at low speed and high brake mean effective pressures. This would probably call for larger bearings, cooled exhaust valves and cooled pistons so that ring sticking would be avoided. This would mean engines designed along the lines of heavy duty industrial engines. —W. L. HULL
University of Illinois

Ed—Here's a chance for some lively discussion. Any comments?

Where Can I Get It?

Chrome-Passivated Zinc Parts

To the Editor:

A couple of months ago we read in a feature article in PRODUCT ENGINEERING of a method for chrome passivating zinc galvanized articles to produce a brassy golden color and superior corrosion resistance.

We have had some difficulty in finding a supplier for this service. Could you advise us of a name and address of a company that does this work, preferably somewhere in the New York-Philadelphia area?

—R. E. BRUCKNER
P. Ballantine & Sons

Ed—New Jersey Zinc's Cronak proc-

Accurate
"know how"

SPRINGMAKING "know how" —and, of course, modern manufacturing facilities—can mean a lot to spring users. The three springs illustrated above are good examples of how Accurate can slash spring costs with modern methods. Where previously multiple operations and intensive inspection was required in the manufacture of these springs, Accurate was able to develop means of producing each in a single operation so accurately that inspection by the users could be eliminated or substantially reduced. And the unit price of each is a fraction of a cent! Since tens of millions of each of these are in daily use the overall savings are very sizable.

We'd like to show those of you who are users of large quantities of springs how we can cut *your* costs. Write or call today.

Accurate Springs

A dependable source of supply!

ACCURATE SPRING MFG. CO.
3815 W. Lake St. • Chicago 24, Ill.

Springs, Wire Forms, Stampings

ess should be the answer to this problem. Try one or more of the following companies, all located in Newark, New Jersey: Four Plating Co., Inc., 222 Thomas St.; The Pyrene Mfg. Co., 560 Belmont Ave.; Hy-Grade Electro Plating Co., 34 Fourth Street.

Metallized-Glass Supplier

To the Editor:

Your reply to Mr. Fishberg's inquiry regarding a source of supply for hermetically-sealed glass tubing as published in the Our Readers Say columns for March could have mentioned the Corning Glass Works, along with the other three companies.

We are old hands at this game of making specialized glass components that have metallized surfaces. Also, our method of soldering glass to form a permanent seal has proved successful for a number of years.

—P. M. REYNOLDS
Corning Glass Works

Ed—Many thanks to Mr. Reynolds for jogging our memory.

"South Pacific" Paint

To the Editor:

Reference is made to the January 1950 issue of PRODUCT ENGINEERING, page 3, on which there is described a non-porous paint applied by spray through an acetylene flame.

Our painting problem on the outer Pacific islands is one for which we have found no completely satisfactory solution. It would be appreciated if you would send us all the information you have on this product.

—R. W. PULLING
Honolulu, Hawaii

Ed—This mixture of quick-setting oils and resins may very well be the answer to your South Pacific painting problems. Mr. Herbert Harris, whose address is 319 E. 44th St., New York City, can supply full particulars.

Ring Springs

To the Editor:

In the January 1950 issue of PRODUCT ENGINEERING there is as article on "Characteristics of Ring Springs by Tyler G. Hicks. Can you tell me if these ring springs are commercially available and, if so, what size and by whom.—CARL A. COVINGTON
Alexandria, Va.

Ed—Ring springs are tailor-made parts made from special-analysis alloy steel. The Edgewater Steel Company, Pittsburgh 30, Pennsylvania, makes them.

1 PUT NEW SELLING POWER IN YOUR PRODUCT!

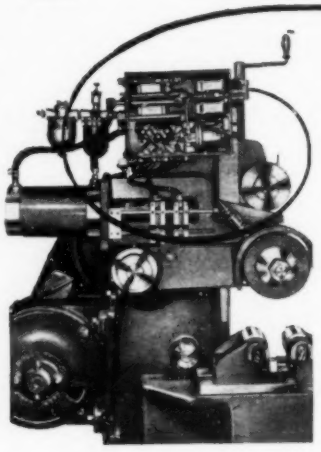
2 INCREASE YOUR PRODUCTION EFFICIENCY!

with REVOLUTIONARY

HY-CYCLIC AIR VALVES

FOR EXAMPLE:

STEEN HIGH SPEED PIPE & TUBE CUT-OFF MACHINES NOW FEATURE HI-CYCLIC VALVE-OPERATED CUTTER ATTACHMENTS

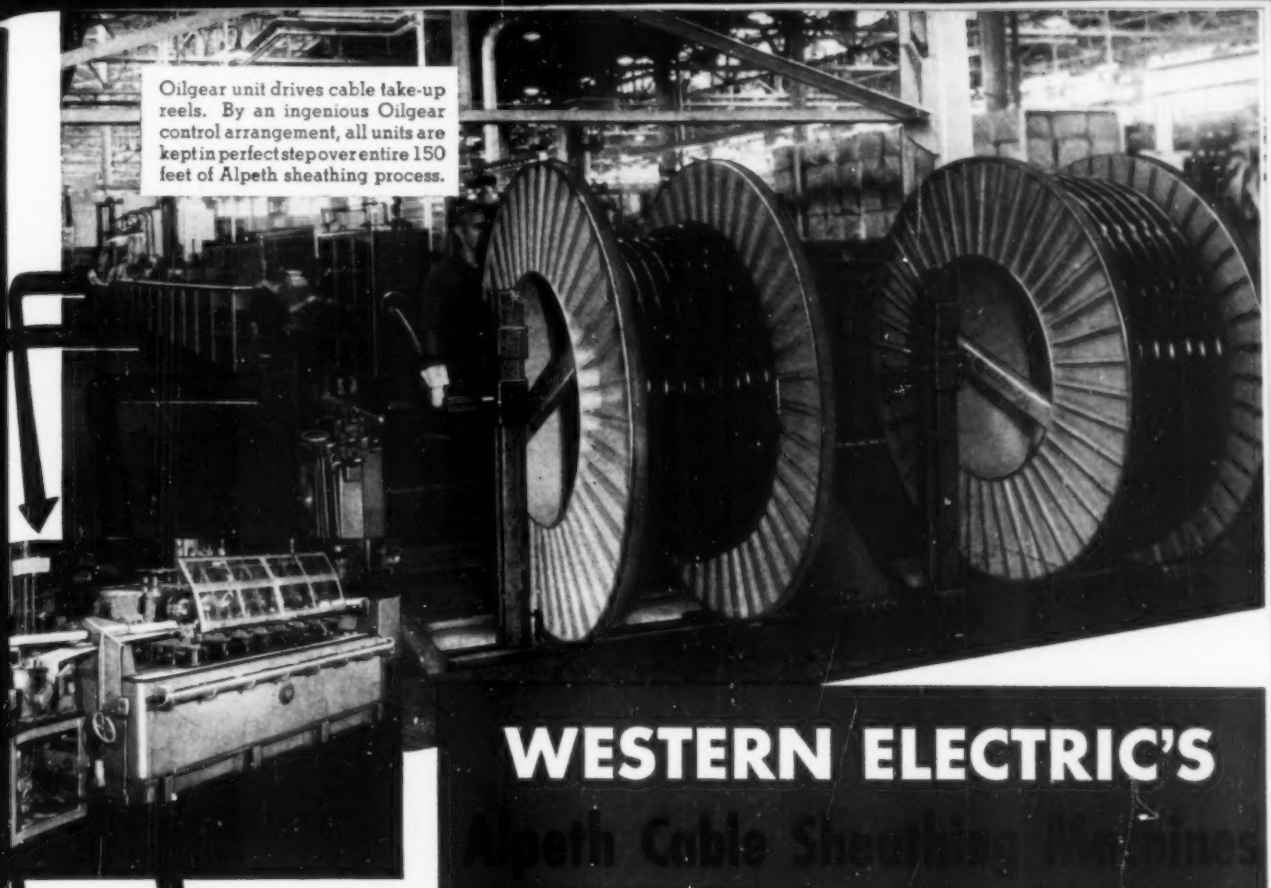


CONTINENTAL Machine Company, Chicago, has greatly increased productivity of Steen Pipe & Tube Cut-Off Machines—increased cutter life—eliminated worker fatigue—by using Beckett Hi-Cyclic Air Valves to operate the cutter attachment. Here's how:

When operator steps on foot switch, air cylinder, controlled by precision Hi-Cyclic Valves, makes a *fast* approach of the blade to the pipe. There's a *split second slow-down* to allow the blade to make *gentle contact* with the pipe and start revolving it—*then*, steady, powerful pressure is applied, cutting the pipe at high speed. The blade is then automatically retracted for the next cut. Every action is fully and completely controlled—*without hydraulic checks*—by the Beckett Hi-Cyclic Air Valves!

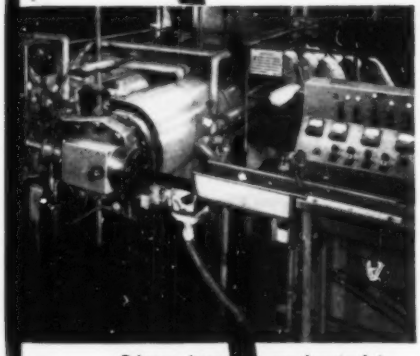
Hi-Cyclic Air Valves provide—for the *first* time—*absolute control of air power!* Investigate this remarkable new development in air engineering. Write for bulletin describing Beckett Hi-Cyclic Basic, Single and Double Solenoid, Piloted and Hydraulic Valves.

BECKETT-HARCUM CO.
1141 Wayne Rd.
Wilmington, Ohio



Oilgear unit drives cable take-up reels. By an ingenious Oilgear control arrangement, all units are kept in perfect step over entire 150 feet of Alpeth sheathing process.

Oilgear fluid p[illegible]r drives Yoder roll forming machine which [illegible]aps corrugated aluminum sheathing arou[illegible]able.



Oilgear drives [illegible] synchronized to speed of Royle [illegible]der which covers cable with melt[illegible]olyethylene.

[illegible]ctor capstan powered by Oilgear, which pulls cable [illegible]ugh extruder, long cooling trough and inspection [illegible]on.

WESTERN ELECTRIC'S Alpeth Cable Sheathing Machines use OILGEAR FLUID POWER drives

• Right after the war, the Bell System faced a tremendous problem because of the shortage of lead for sheathing telephone cable. To solve that problem, a newly designed sheath known as Alpeth—aluminum polyethylene—was adopted. And the engineers had to design a machine fast that would apply this sheath fast—to produce this new cable by the millions of feet.

Oilgear engineers, working with *standard* Oilgear Fluid Power pumps, motors and valves, met the need for drives that would handle the complex Alpeth coating machines, dependably, without trouble . . . and for drives that could be immediately, easily and economically installed . . . requiring minimum space, sure performers from the start.

The first Alpeth cable sheathing machines installed by the Western Electric Company proved themselves and more units were installed, to make a total of three at the Kearny, N. J., Works and three at Hawthorne Works in Chicago. The Oilgear drives have performed well, without trouble, with minimum maintenance, often at high speed for 24 hours a day.

A company like Western Electric does not buy by guesswork. Neither should you. THE OILGEAR COMPANY, 1571 W. Pierce Street, Milwaukee 4, Wisconsin.

Oilgear

PIONEERS IN FLUID POWER

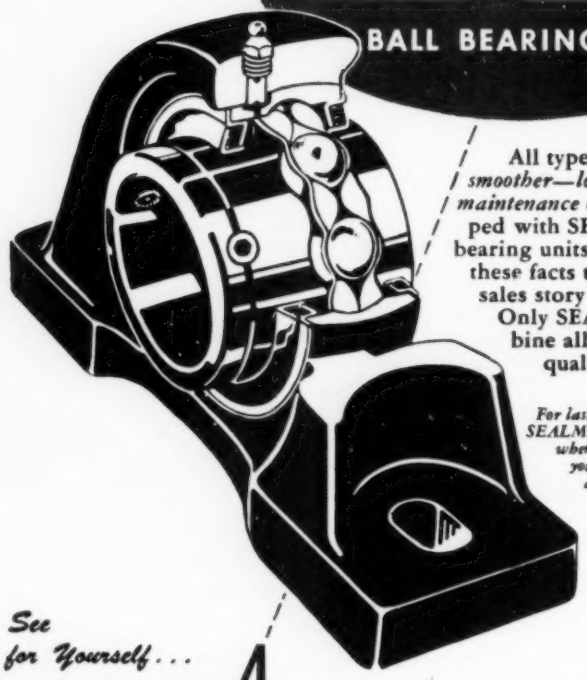
PUMPS, MOTORS, TRANSMISSIONS, VALVES, CONTROLS

Put the BEST POSSIBLE Bearing Performance Into YOUR Products

by installing

SEALMASTER

BALL BEARING UNITS

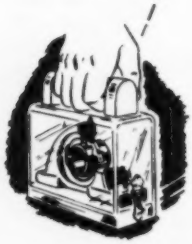


All types of equipment run *smoother—longer*—with *lower maintenance costs*—when equipped with SEALMASTER ball bearing units. Capitalize on these facts to supplement your sales story of other features. Only SEALMASTERS combine all essential bearing qualities *in one unit!*

For lasting satisfaction, specify SEALMASTER ball bearing units when designing or re-designing your line. Write today for a copy of SEALMASTER Catalog No. 845.

See for Yourself . . .

why SealMasters operate so smoothly...and last so long. Ask the SealMaster engineer to show you this cut-away pillow block which shows every detail of SealMaster's exclusive combination of features.



4 Big Reasons Why Your Machines Should Have SEALMASTER Bearings

1. **PERMANENTLY SEALED!** Felt-lined steel flinger rotating in labyrinth prevents entry of dirt or loss of grease.
2. **SELF-ALIGNING!** Bearing unit, with seals independent of housing, aligns itself without seal distortion.
3. **PRE-LUBRICATED!** Proper amount of lubricant is placed in bearing chamber before shipment . . . unit is ready for immediate use.
4. **NO HOUSING WEAR!** Patented locking pin and dimple prevents rotation of outer race in housing, and positions bearing for relubrication . . . No housing wear means quiet operation.

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STEPHEN S-A ADAMSON MFG. CO.

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NEW BOOKS

Introduction To The Theory Of Statistics

ALEXANDER M. MOOD, *The Rand Corp., formerly Professor of Statistics, Iowa State College.* 433 *pages,* 6 x 9 *in. Published by the McGraw-Hill Book Co., Inc.,* 330 *W.* 42*nd St., New York* 18, *N. Y.* $5.

Data used as text material in a senior year course in Statistics are the basis for this book. A prior mathematical acquaintance with partial differentiation, multiple integrals and Taylor series is required. No previous knowledge of statistics is assumed and the necessary concepts and models of probability are dealt with in the first few chapters.

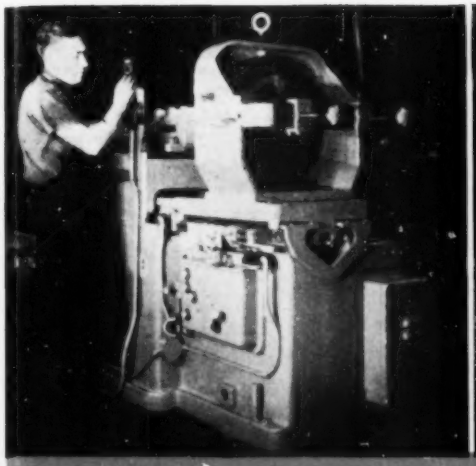
Mathematical rigor has been avoided by the author wherever possible, in a self-confessed effort to hold the reader's interest. Practical sidelights are provided and the 500 problems supplementing the text illustrate ways in which the theory is applied.

After covering probability theory, the author discusses, in detail, the distribution and sampling theory. With this ground work, the estimation of quantities and the testing of hypotheses are covered. Chapters on sequential analysis and distribution methods represent recent advances in the field. A discussion of the multi-variate normal distribution and a treatment of the analysis of variance are included as special topics.

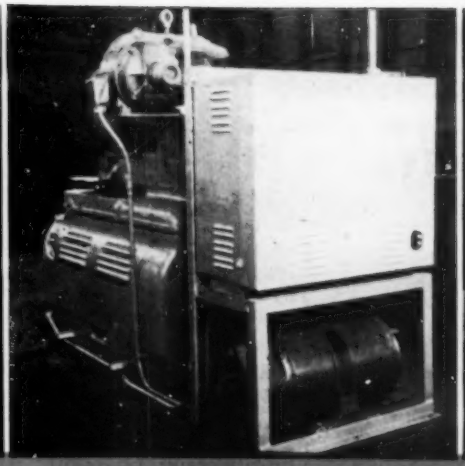
Electrical Machinery

FRED A. ANNETT, *Associate Editor, Power Magazine,* 458 *pages,* 6 x 9 *in. Published by McGraw-Hill Book Co., Inc.,* 330 *W.* 42*nd St., New York, N. Y.* $3.75.

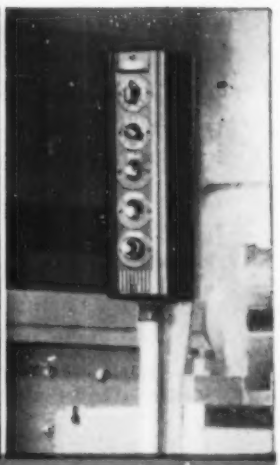
This book covers, step by step, the installation, operation and maintenance of electrical machinery. Starting with magnetism, the properties of permanent and electro magnets, and electric circuits, it goes on to discuss the application of these fundamentals, showing how theory fits into practice. It explains how electrical instruments are constructed, how meters operate, and how meters are used to make measurements. It analyzes the principles of dynamo-electric machinery and treats the different types of d-c and a-c motors and generators. Two-phase and three-phase circuits, operat-



Two separate Speed Selector Controls are used for this automatic 2 cutting speed operating cycle.



Rear view illustrates control equipment and drive motor on top of machine.



The top two small dials provide an extremely wide range of optimum surface cutting speeds. A twist of the finger instantly changes the speed.

Production Has Increased
Machining Quality Is Improved
Accuracy Is Held Closer
Set-Up Time Is Reduced

Since Replacing a Conventional Motor With

Century SELECTIVE SPEED Drive

ON THIS BORING MACHINE

This is just one typical example of the time and labor saving advantages which may be incorporated in new machines — or which may be installed on equipment now in use.

Century Selective Speed Drives have been operating as long as 25 years in such places as steel mills, rubber mills, paper mills, wire mills, printing plants and machine shops. These drives are ideal wherever production processes require a wide range of stable speeds.

Ratings are available in sizes from **1 to 150 horsepower.** Speed range of 8 to 1 is standard — up to 32 to 1 is available.

The complete line of Century motors includes wide range of types and kinds from 1/6 to 400 horsepower — single phase, polyphase and direct current.

SPECIFY Century C MOTORS **ON YOUR EQUIPMENT . . .** or call the Century office located near you.

CENTURY ELECTRIC COMPANY 1806 Pine St. • St. Louis 3, Missouri

Offices and Stock Points in Principal Cities

Here's how to anchor a cordset to an electrical appliance

to Increase Product Life

Slip a HEYCO Nylon Strain Relief Bushing on wire. *(Heycos eliminate cord wear at chassis entrance.)*

Snap HEYCO into chassis hole. *(The Heyco imparts a positive non-slip grip; does not injure wire.)*

HERE'S WHAT A HEYCO WILL DO

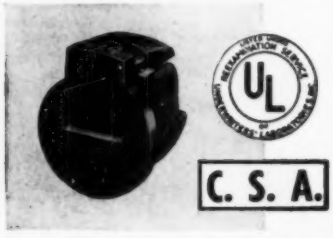
1. Save time—reduce costs
2. Absorb cord pull, push and torque
3. Insulate wire at chassis
4. Prevent fraying
5. Eliminate tying knots
6. Improve appearance of product

HEYCOS ARE USED ON MANY PRODUCTS

You will find HEYCOS being used on an increasing number of nationally known appliances . . . toasters, heaters, clocks, roasters, mixers, record players, radios, television sets, toys, lamps, polishing machines, etc.

HEYCOS ARE MADE IN 11 SIZES

for clock wire to S-10/3 cable



APPROVED

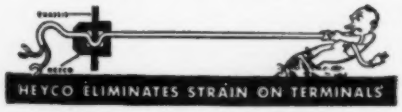
C. S. A.

MAKE SURE YOUR PRODUCT IS DOUBLY PROTECTED BY A HEYCO STRAIN RELIEF

HEYCO

HEYMAN MANUFACTURING CO.

KENILWORTH 3, N. J.



ing alternators in parallel, power factor, transformers, electronics, etc., are all explained in a simple, practical manner.

Because of the huge strides made in the field of industrial electronic applications, this revised third edition includes a wealth of specific material on electron tubes and the circuits in which they are used. Emphasis is on such timely applications as: changing alternating current to direct current; operation of adjustable speed d-c motors from a-c circuits; and smoke-density and flame-failure devices.

Engineering Economic Analysis

Second edition. CLARENCE E. BULLINGER, *Professor of Industrial Engineering and Head of the Department of Industrial Engineering, Pennsylvania State College. 397 pages, 6 x 9 in. Published by McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York 18, N. Y. $4.*

This is a revision of a successful text that discusses in detail the economic factors of engineering projects, shows how to evaluate such factors and to estimate costs, and how to separate and define intangibles. Methods and problems inherent in the financing of a project are also included.

Many changes have been made in the second edition to clarify certain material or to incorporate new developments in the field during the past seven years. These changes include: A new chapter on minimum cost analysis; a new chapter on the intangible analysis of a project; sections added on declining balance method for depreciation; estimation of direct labor and material calculations, as well as expense distribution; electric-utility rates and estimation of expenses for power utilities.

Other text material changes include: Revised statistical analysis, expansion of the section on bonds and bond redemption; some additional and revised tables; clarification of charts; a new solid cost diagram; addition of logarithm tables and many new problems.

Index of Nomograms

DOUGLAS P. ADAMS, *Assoc. Prof. of Graphics, Massachusetts Institute of Technology. 174 pages, 7 x 9½ in. Published by John Wiley and Sons, Inc., New York, N. Y. $4.*

This book is the first listing of the many nomograms that have appeared in American periodicals during the

CONTROLLED TENSION
...built into every lock washer by exclusive manufacturing process and precision heat treating.
DIAMOND G SPRING LOCK WASHERS
POSITIVE HOLDING POWER
. . . under all conditions is assured by torture-tests in Garrett's laboratories . . . performance-proof on all types of products.
DIAMOND G SPRING LOCK WASHERS
LONGER SERVICE
. . . with correct tension on bolt, nut and assembly parts prevents loosening, provides extra protection on every product.
DIAMOND G SPRING LOCK WASHERS
AT YOUR SERVICE
Garrett's line of lock washers, engineering service and quick deliveries . . . plus many other metal parts. Write for lock washer handbook.
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DEPENDABLE SMALL MOTORS

- Forced-Air Bathroom Heaters
- Radio-Phonographs
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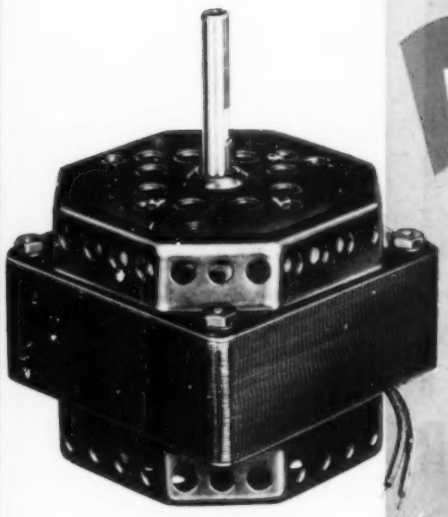
- Kitchen Fans
- Action Displays
- Sound Recorders

try these *Smooth Power* champions

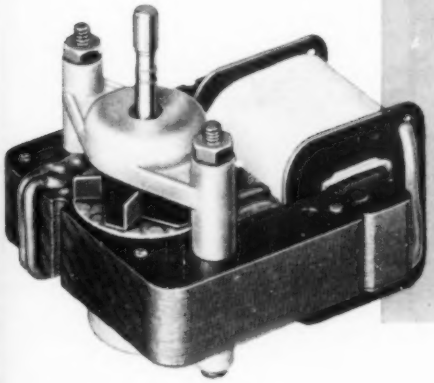
Dependability . . . that, in one word, tells a mighty important story about General Industries *Smooth Power* small motors—1/50 H.P. and under. From exacting specifications of the materials which go into their manufacture, to precise final inspection of the finished product, these motors are made to provide long, trouble-free performance wherever they're used.

All are extremely compact . . . light in weight . . . low in cost. They are available for either clockwise or counter-clockwise rotation. Design modifications may be had on large-quantity orders.

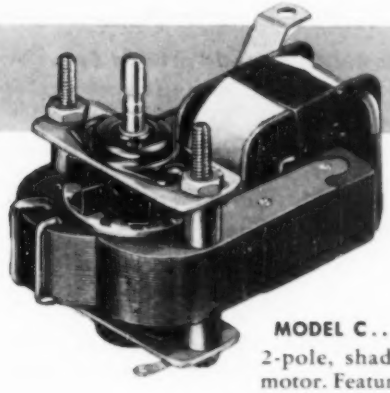
Write today for blueprints and quotations upon your requirements.



MODEL D . . . 1/50 to 1/100 H. P.
4-pole, shaded pole induction motor. Features include scientifically designed air intake . . . dual cooling fans . . . self-aligning, oiless sleeve bearings.



MODEL A . . . 1/125 to 1/200 H. P.
2-pole, shaded pole induction motor. Features include novel bearing construction which insures rigid and permanent alignment of motor shaft . . . oiless bearings.



MODEL C . . . 1/250 to 1/500 H. P.
2-pole, shaded pole induction motor. Features include accurately aligned motor shaft . . . oiless bearings.

The GENERAL INDUSTRIES Co.

DEPARTMENT D • ELYRIA, OHIO

Elapsed time intervals can be measured down to 1/1000th second with a

STANDARD PRECISION TIMER

The world's most accurate (and rugged) time measuring instrument. Available in 8 models as shown below:

MODEL	READS	TOTALIZES	ACCURACY
S-100	1/5 sec.	6000 sec.	± .1 sec.
S-60	1/5 sec.	60 min.	± .1 sec.
SM-60	1/100 min.	60 min.	± .002 min.
S-10	1/10 sec.	1000 sec.	± .02 sec.
S-6	1/1000 min.	10 min.	± .0002 min.
S-1	1/100 sec.	60 sec.	± .01 sec.
MST	1/1000 sec.	.360 sec.	± .001 sec.
MST-500	1/1000 sec.	30 sec.	± .002 sec.

Manually and Electrically Operated Portable Cases or Panel Mounting optional changes to conform to customers' requirements.

Special Timing Problem. **Our engineers are ready to consult with you, and design timers to meet special timing problems.**

OTHER PRODUCTS

Standard Chrono-Tachometers, Custom-built Laboratory Test and Distribution Panels, School Time Program Systems, Hospital Doctor Paging and Nurse Call Systems.

WRITE FOR BULLETIN NO. 153

STANDARD

THE STANDARD ELECTRIC TIME CO.

95 LOGAN STREET **SPRINGFIELD, MASSACHUSETTS**

past 25 years. As an index of over 1,700 published nomograms, this unusual list can serve as a valuable time saver. The index directs the reader to the particular periodical having the chart he needs for the solution of his problem. However, there still remains the difficulty of finding the specific periodical. In spite of this, many hours of complicated construction work can be saved by use of this index.

The book is divided into two sections: Index A—Key words and Index B—Master Index. Index A is an alphabetical listing of one or two words that are associated with the diagram. Following each entry is a key number that corresponds to Index B which contains the periodical, date, volume, number and page number. Index B is divided into twenty-one groups based on the major fields in which the nomograms have been extensively used. Following the title, the variables appearing in each diagram are given. This enables one to understand its contents at a glance.

Welding Handbook

Third Edition, American Welding Society, 33 W. 39th St., New York 18, N. Y. 1650 pages, 6 x 9 in., cloth bound. $12.

Many new developments have taken place in welding since the 1942 edition of the Welding Handbook. The third edition contains much important up-to-date information which should benefit those in the welding field. This book has useful data which can serve not only the designer, engineer, metallurgist, and manufacturer but shop personnel as well.

The subjects are discussed in a most complete way. Beginning with the physics of welding, the metallurgical part of the welding process is described. Plain carbon and alloy steels are included in this section along with non-ferrous alloys.

More than thirty welding and cutting processes are discussed and at great length: First, a description of the equipment, then the use of materials, and the fundamentals as well as limitations of each particular process are given. These processes include brazing, soldering and metallizing.

Problems of using various metals and alloys are described in detail; the necessary precautions which should be observed are discussed. Joint design recommendations and the properties of welded joints are given. Specifications and codes are explained for the design and fabrication of many structures,

Metal sculpture executed in Weirzin steel b
Lyman Beckwith. Photography by Cle Clark
Cutting and shaping of figures demonstrate
exceptional qualities of Weirzin electrolyti
zinc coated steel.

Outwit the weather with a sash that lasts—

Smart girl, this lady of the house. The storm sash she bought is made of *steel*, metal of a million uses.

No other material—only steel—could serve her so well or give her so much value for her money. For steel is easy and economical to fabricate into flawless products. Steel offers a unique combination of strength, durability, adaptability and economy. Steel is produced with the right qualities and characteristics for the exact job it's meant to do.

And so this storm sash, painted to harmonize with the colors of the house, will both outwit the weather and resist the elements. Atmospheric conditions that stain and discolor any unpainted material will not affect it. And it will withstand hard usage with the proved strength of steel.

The same values of steel that make steel sash better also make better products of all kinds—household appliances or kitchen cabinets, wall tiles or lighting fixtures. You can count on steel to serve you best.

rzin Electrolytic Zinc Coated Sheets and Strip
ite Tin Plate and Tin Mill Products
rton Hot-Rolled and Cold-Rolled Sheets and Strip
rton High-Carbon Cold-Rolled Spring Steel
-X High-Tensile Steel

WEIRTON STEEL CO.

WEIRTON, W. VA., Sales Offices in Principal Cities
Division of NATIONAL STEEL CORPORATION, Executive Offices, Pittsburgh, Pennsylvania

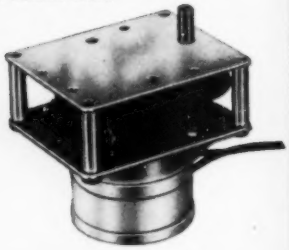
WEIRTON STEEL COMPANY

BATTERY CHARGER-TESTER

TIMED BY Cramer TYPE IG INTERVAL TIMER

Accurate...dependable...the Marquette Charger-Tester, a product of the Marquette Manufacturing Co., is widely used by service stations and garages, by fleet owners and car dealers. At the touch of a button, 20 second test shows true battery condition, gives complete analysis, and indicates exact charging time. Completely automatic, the Charger-Tester is equipped with a Cramer Type IG Interval Timer that provides up to 60 minutes of controlled charging, has "hold position" for overnight or slow charging.

Cramer Type IG Interval Timers are designed for a wide range of built-in applications—microfilming equipment, hair waving machines, laundry dryers, therapeutic machines, extractors, ovens — wherever precision timing control is required for convenience of operation, faster production, maintenance of quality. The Type IG Timer shown below, can also be furnished with a manual starting button (optional). For detailed information, write for Bulletin 130A.



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such as buildings, bridges, tanks, piping, automobile products and aircraft.

Individual chapters are devoted to estimating costs, inspection, welding terms, welding standards and symbols. A large index makes it possible to readily find specific information.

This book represents more than four years of effort and experience of more than 250 experts. Their contributions make this book a good text on welding as a handbook. The material is well illustrated and has a two-column layout which is easy to read. At the end of each chapter is an excellent bibliography for further information or study.

Saturating Core Devices

LEONARD R. CROW, *Director of Research and Development of the Universal Scientific Co., Inc., 373 pages, 6 x 8½ in. Published by the Scientific Book Publishing Co. 530 So. 4th St., Vincennes, Indiana,* $4.20.

Although this book appears to be a compilation of schemes using saturable core magnetic devices, it is not intended as a source for engineers to obtain specific design and performance data but rather as a means to acquaint the elementary student in electric sciences with electric phenomenon not to be found conveniently collected elsewhere. It is hoped to thereby stimulate his interest in electric principles involving direct and alternating currents.

Since the approach is for the benefit of the elementary student, mathematics and cumbersome proofs are avoided; descriptive and graphical methods are utilized to sustain the reader's interest. Moreover, the elementary and basic principles of electricity which are given are not collected at the front of the book but are distributed throughout the book wherever most needed to minimize burdening the elementary electrical student with too much theory at one time.

Having awakened the interest of the student by electric, electronic, and magnetic phenomenon which are practical and may be demonstrated by equipment supplied by educational supply houses, it is hoped that the reader with an elementary background in electricity will refer to excellent electric textbooks dealing with both d-c and a-c fundamentals.

This book offers a collection of simplified description's of saturable core devices and applications. As a further feature, a good bibliography on saturable core reactors and related subjects is included at the end of the

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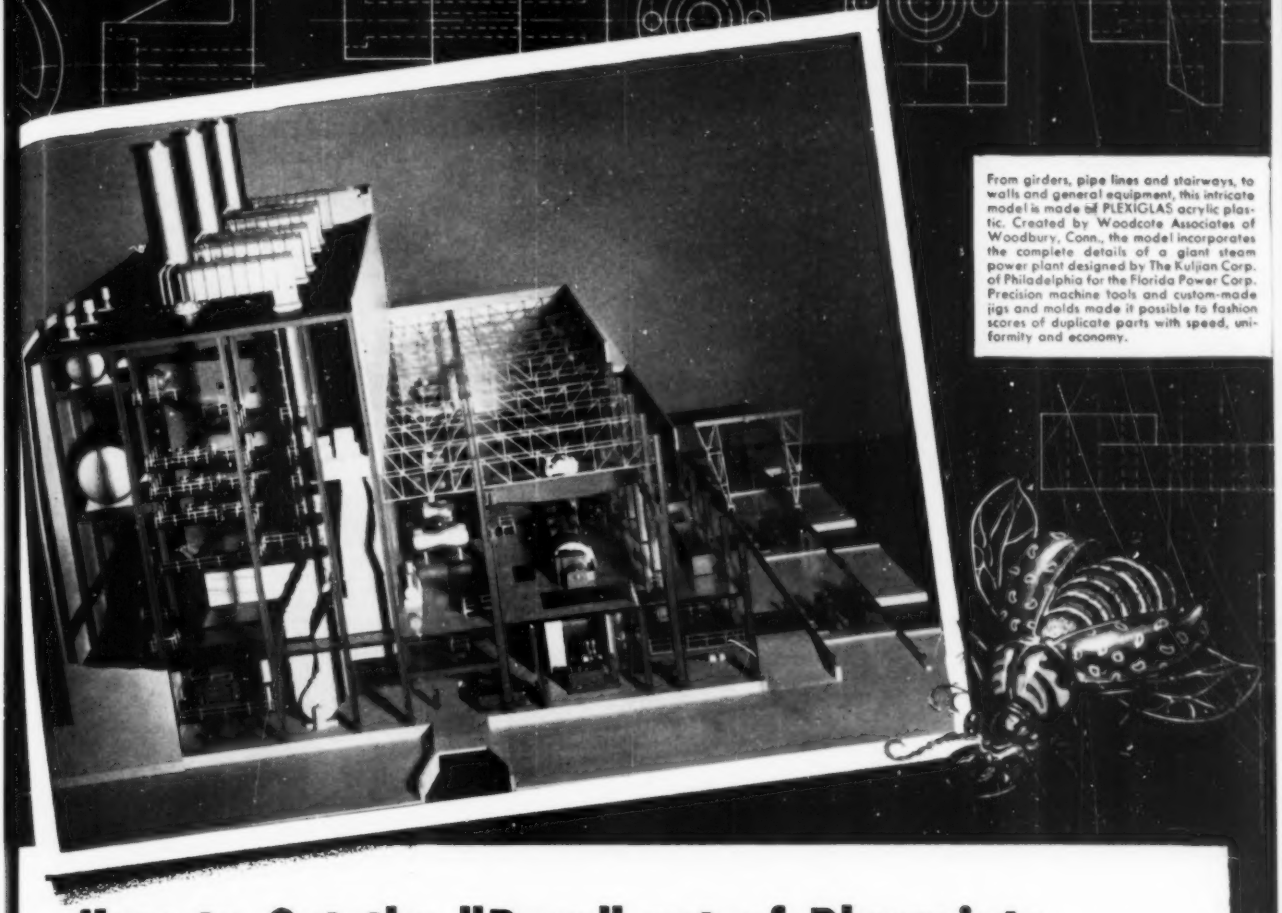

From girders, pipe lines and stairways, to walls and general equipment, this intricate model is made of PLEXIGLAS acrylic plastic. Created by Woodcote Associates of Woodbury, Conn., the model incorporates the complete details of a giant steam power plant designed by The Kuljian Corp. of Philadelphia for the Florida Power Corp. Precision machine tools and custom-made jigs and molds made it possible to fashion scores of duplicate parts with speed, uniformity and economy.

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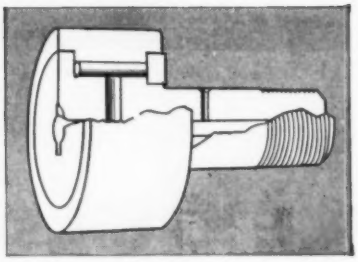

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book for the design or practicing engineer's use. This should prove a great time saver and should satisfy the demands of readers.

Sample chapters include Applications and Modifications of D-C Controlled Saturable-Core Reactors; Permanent Magnet Controlled Saturable Core Reactor; Peaking Transformers and Voltage Waveforms; and Saturable Core Type Servomechanisms.

Stress and Strength Of Manufactured Parts

C. LIPSON, G. C. NOOL, *and* L. S. CLOCK. 275 *pages*, 6 x 9 *in. Published by McGraw-Hill Book Co., Inc.*, 330 *W. 42nd St., New York, N. Y.* $4.50.

This work has been prepared as a handbook for designers, engineers and metallurgists and, as such, is filled with specific data which should be useful in the prevention and elimination of machine part failures. The authors have gathered and presented considerable data on stress concentrations and strength of steel members which are based on the hardness and surface condition.

The book is divided into two parts: Part I deals with general principles of stress and strength. The treatment in this section discusses basic concepts as related to both stress and strength. It does not provide specific formulas or equations to determine the stress in particular structural members. Part II consists of a large selection of charts on stress concentration factors. These factors are grouped into the geometric, the fatigue of annealed steel and the fatigue of quenched and drawn steels. The stress concentration factors are conveniently expressed graphically in 139 charts. Allowable stress based on the hardness are given for either finite or infinite service life.

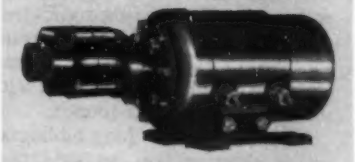
The appendix contains an excellent list of references totaling 270, which are arranged according to the year of presentation.

Fundamentals In The Production And Design Of Castings

CLARENCE T. MAREK, *Associate Professor of Manufacturing Processes, Purdue University.* 5⅓ x 8½ *in.*, 383 *pages. Published by John Wiley & Sons, Inc.*, 440 *Fourth Ave., New York* 16, *N. Y.* $4.

The author believes that the responsibilities of the engineer who designs engineering parts are twofold. He

Another Job for Pesco HYDRAULIC MUSCLES



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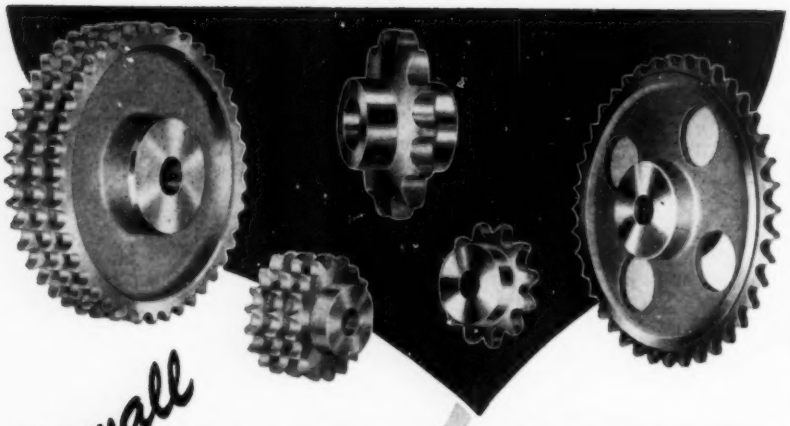

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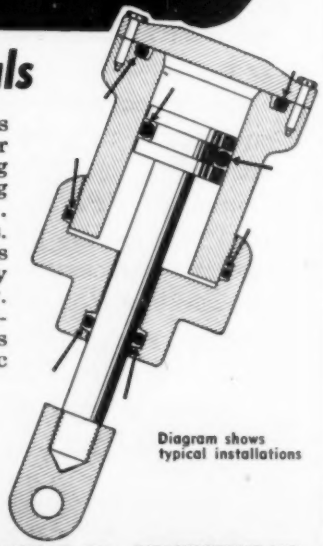

Diagram shows typical installations

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must design the part so that it will perform a certain function and he must also design the part so that it can be produced at the least expenditure of labor and material.

The first seven chapters are general background material and cover all phases of the broad field of casting. They are easy reading for a clear and concise understanding of the basic casting processes, mold construction, foundry sands and sand control, patterns and related equipment, cores and their applications, foundry production equipment and production planning.

Casting materials are the subject of the next three chapters. Many photomicrographs, charts, diagrams and tables make the discussions of the physical and metallurgical properties of cast metals, the properties and uses of both ferrous and nonferrous cast metals highly valuable.

About fifty pages are devoted to the design factors relating to cast parts. Economy factors deal with redesign to eliminate cores, selection of production method, effect of quantity, choosing the parting plane, and the use of cast-weld constructions.

Chapter 14 covers the design factors to be considered so that defects will not develop during production and service. Some of the topics treated are rate of solidification; directional solidification; "L" and "V" sections; bosses, bolting pads and raised letters; shrinkage; fillets and rounds.

Finally, there is a long bibliography and a short section on sand testing and control procedures.

Industrial Inspection Methods

LENO C. MICHELON, *Assistant Professor of Industrial Management, Purdue University.* 568 *pages,* 6 x 9¼ *in. Published by Harper & Bros.,* 49 *E.* 33*rd St., New York, N. Y.* $6.

This book should serve as a good text for engineering students who anticipate quality control work in production departments. It contains a considerable amount of descriptive material relating to inspection tools, techniques, and methods of inspection. It was first published in 1942 and has been revised to include new inspection equipment and procedures which were developed during the war. At the end of each chapter there is a series of review questions, and in some cases problems for review purposes.

This book is divided into five sections. They are: Basic Concepts of Industrial inspection; Dimensional Control; Testing for Physical and

setting new standards for electrical instruments

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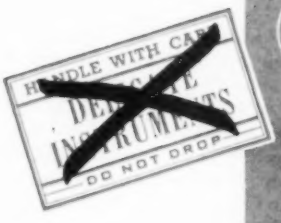

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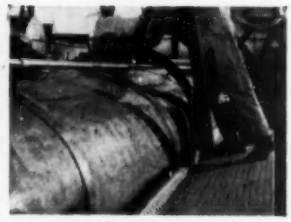

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Mechanical Properties, Superficial Inspection Methods; and Inspection Organization and Personnel. The book is profusely illustrated with drawings and sketches illustrating various devices used in making measurements. Much space is devoted to describing the proper use of the inspection equipment and as a result, it is quite elementary. The subject matter and style of this book lends itself well to industrial training programs of shop personnel.

Modern Methods of Gear Manufacture

National Broach and Machine Co. Third Edition. 172 *pages,* $8\frac{1}{2}$ x $10\frac{1}{2}$ *in. Published by the National Broach and Machine Co., Detroit, Mich.* $10.

This third edition has more than double the number of pages of its predecessor, which was published in 1942. Of necessity the scope of the book has been increased as a result of the impact of war developments on gear practice, the rapid progress made since the war, and the increased gear accuracy and economy of gear production achieved in the past seven years.

The content of this book is a fund of information compiled from an accumulation of answers to the many questions that frequently perplex the designer, the manufacturer and the user of gears.

Presented in nine chapters, the subject matter is classified as follows: Gear design principles; gear formulas; selection of gear steels and forging; heat-treatment of gear steels; machining gears; advanced production practices; special gear problems and case histories; red ring products; and gear broaching.

In general, the volume is designed to acquaint and to impart to the reader a better understanding of the functions of gear elements and their interdependence. Case histories are discussed that emphasize the necessity for providing proper tooth contact areas and assuring the maintenance of such contact areas under normal service conditions. Accordingly much attention is devoted to precision control of tooth form, accurate alignment of gear centers, limitation of structural deflections, selection of gear materials and heat-treatment, the restriction of backlash to required clearance values and the relief or clearance to avoid concentration of leads.

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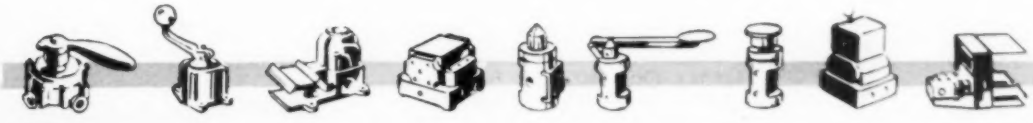

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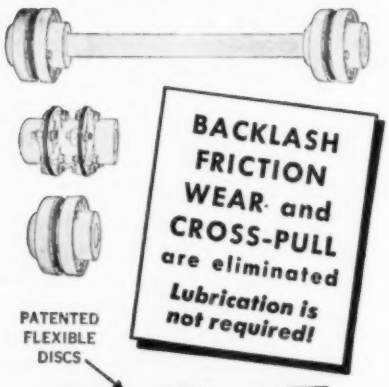

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Industrial Electricity Vol. II, Alternating Currents

WILLIAM H. TIMBIE and FRANK G. WILLSON. 781 *pages*, 6 x 8½ *in. Published by John Wiley & Sons*, 440 *Fourth Ave., New York* 16, *N. Y.* $5.96.

Written primarily as a textbook, great emphasis has been placed on understanding fundamental principles of modern electrical engineering. The procedure followed in this book is first to note what happened, then work out why it happened, and finally test the theory by applying it to several similar conditions. For simplicity, the mathematics of this book have been limited to algebra and a few simple trigonometric equations. The first volume of this Industrial Electricity Series is devoted to direct-current practice.

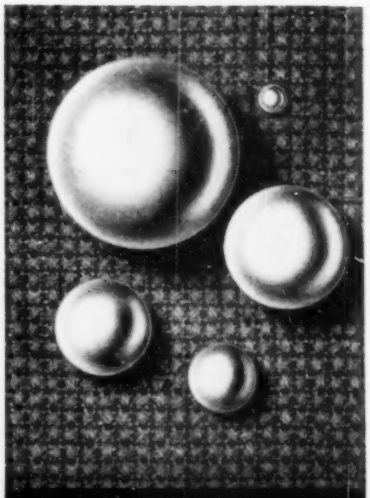
The extensive teaching experience of the authors has been applied in this text to insure that students will acquire a firm grasp of the basic principles. At the end of each chapter there are numerous problems covering various fields. In addition, there are five hundred diagrams and illustrations of modern machines and apparatus. The arrangement is such that it is equally suited to engineering schools or individuals who wish to learn, by themselves, the fundamentals of alternating current in industrial electricity.

Heat Pump Applications

EMORY N. KEMLER, *Assoc. Director, Southwest Research Institute and* SABERT OGLESBY, JR., *Instructor in Electrical Engineering, Purdue University.* 300 *pages*, 6 x 9 *in. Published by the McGraw-Hill Book Co., Inc.*, 330 *W. 42nd St., New York* 18, *N. Y.* $6.

Here, in nontechnical language, is a practical discussion of the industrial, residential, and commercial applications of the heat pump, both in the U. S. and in Europe, including its

a metal ball PROBLEM?



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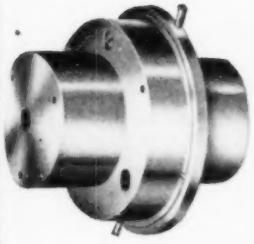

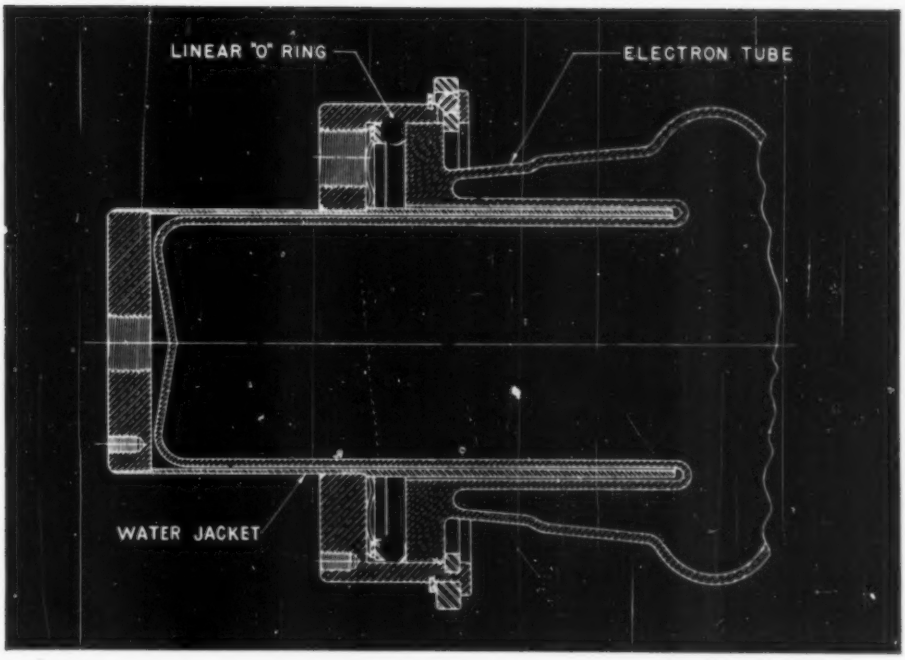

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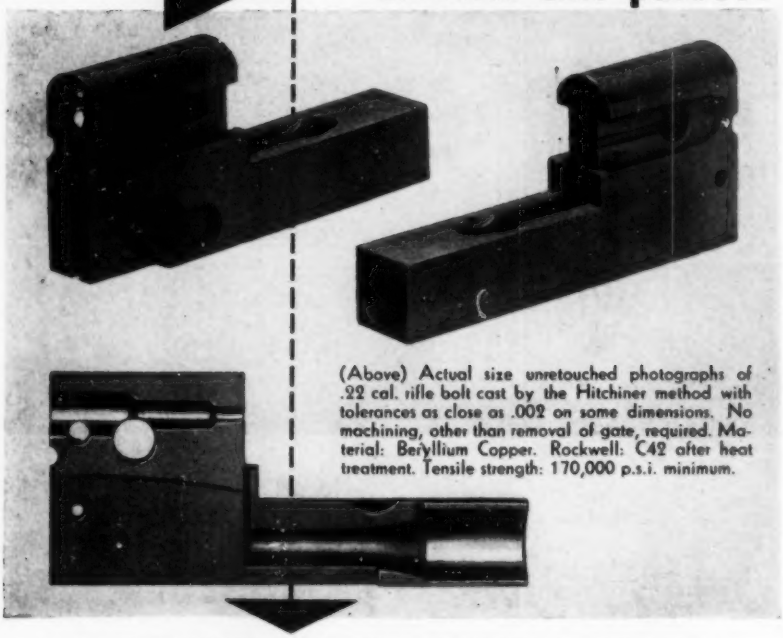

(Above) Actual size unretouched photographs of .22 cal. rifle bolt cast by the Hitchiner method with tolerances as close as .002 on some dimensions. No machining, other than removal of gate, required. Material: Beryllium Copper. Rockwell: C42 after heat treatment. Tensile strength: 170,000 p.s.i. minimum.

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From a general discussion of modern applications, the book proceeds to heat pump cycles and the thermodynamics of the heat pump. Many illustrative examples make the material easy to understand and follow. For those interested in the details of heat pump elements, the book describes such specific items of equipment as compressors, fans and ducts, electric motors and accessories.

Temperature and design data have been included, and liberal use has been made of illustration. With this book, those who are concerned with designing heating systems can reap the benefit of past developments in connection with heat pump installations. A final chapter gives a patent survey for those having a more technical interest in this subject.

Nonlinear Vibrations In Mechanical And Electrical Systems

J. J. STOKER, *Professor of Mathematics, Institute for Mathematics and Mechanics, New York University.* 273 *pages,* 6 x 9 *in. Published by Interscience Publishers, Inc., 215 Fourth Ave., New York* 3, *N. Y.* $5.

The principal aim of this text is not so much to introduce methods of improving the accuracy obtainable by linearization, but rather to focus the attention on those features of the problems in which the nonlinearity results in distinctive new phenomena.

Underlying principles and theory are presented so that they can be easily understood by engineers whose primary interest is in applying the ideas and methods to concrete physical problems. While the main types of problems can be treated rather satisfactorily with the knowledge and use of little more mathematics than elementary differential equations, the problems do lead to questions of great interest from the mathematical point of view.

There are six chapters in the main body of the book, and six Appendices. The first five chapters are elementary in character, the six chapter is less elementary, while the Appendices contain rigorous existence and uniqueness proofs.

The chapters discuss linear vibrations; free vibrations of undamped systems with nonlinear restoring forces; free oscillations with damping and the geometry of integral curves; forced oscillations of systems with nonlinear restoring force; self-sustained free and forced oscillations;

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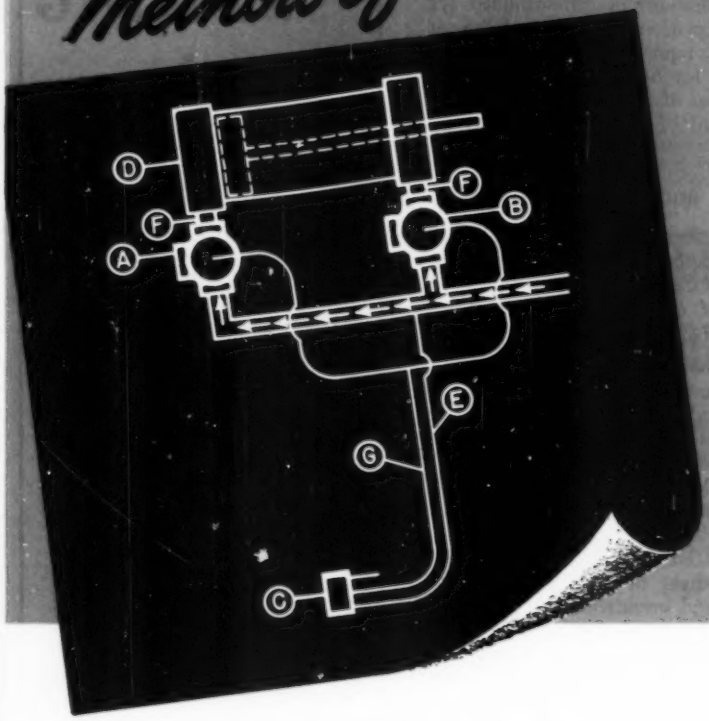

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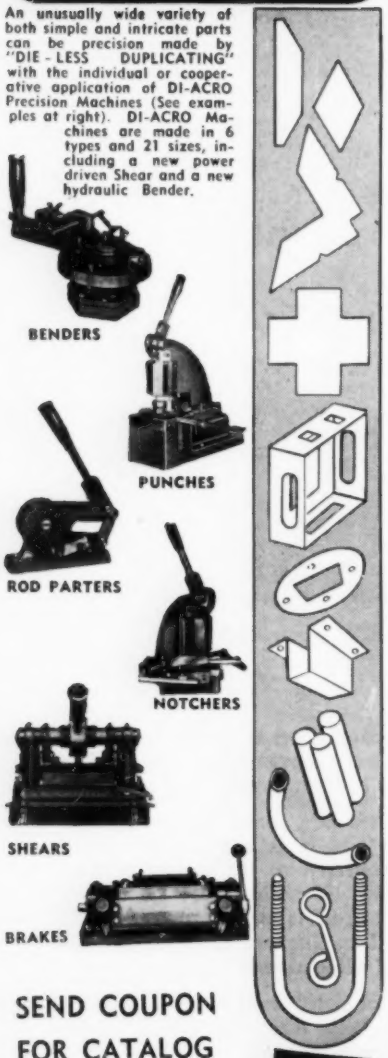

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and Hill's equation and its application to the study of the stability of nonlinear oscillations.

In the Appendices the following subjects are given a rigorous mathematical treatment: Mathematical justification of the perturbation method; the existence of combination oscillations; the existence of limit cycles in free oscillations of self-sustained systems; relaxation oscillations of the van der Pol Equation; the criterion of Poincaré for orbital stability; and the uniqueness of a limit cycle in the free oscillations of a self-sustained system.

Science and the Goals of Man

ANATOL RAPOPORT, *Assistant Professor of Mathematical Biology, University of Chicago.* 5¾ x 8½ *in.*, 262 *pages. Published by Harper & Brothers,* 49 *E.* 33*rd St., New York, N. Y.* $3.50.

This book is concerned with the basic question which confronts every person today dealing with the means and ends of scientific inquiry: Is science merely a tool, or can it be a way of life? To this Dr. Rapoport replies that there should be no fundamental cleavage between science and ethical values, and he here demonstrates that in modern scientific method and orientation rest the foundations of individual and social sanity.

This book might be questioned by some, since Dr. Rapoport does not seem to account for the place of motions in the determination of human thought. However, for those of us who are willing to think rationally, this is a book of extraordinary value. The book explains the general social and personal significance of relativity. It analyzes and qualifies why and how people disagree and how they can reach agreements. (Assuming again that all parties to the disagreement are rational.) Also, it explains how scientists think and presents what Dr. Rapoport considers to be the ethical basis of science.

Whether or not you agree with Dr. Rapoport, this book offers a stirring intellectual experience.

ASTM Standards, 1949, Part I, Ferrous Metals

6 x 9¼ *in.*, 1,372 *pages. Published by the American Society for Testing Materials,* 1916 *Race St., Philadelphia* 3, *Pa.* $10.

This is the first of the six volumes covering the new edition of the ASTM standards. Concerned specifically with ferrous materials, the new volume

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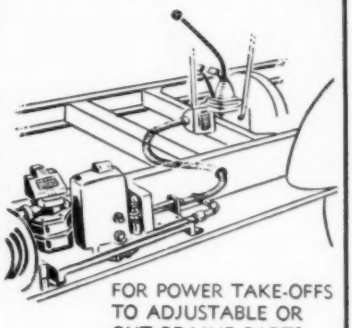

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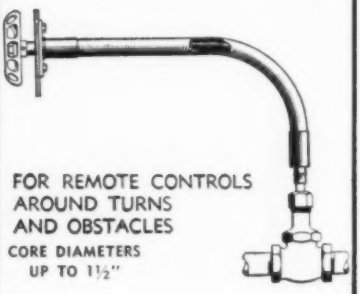

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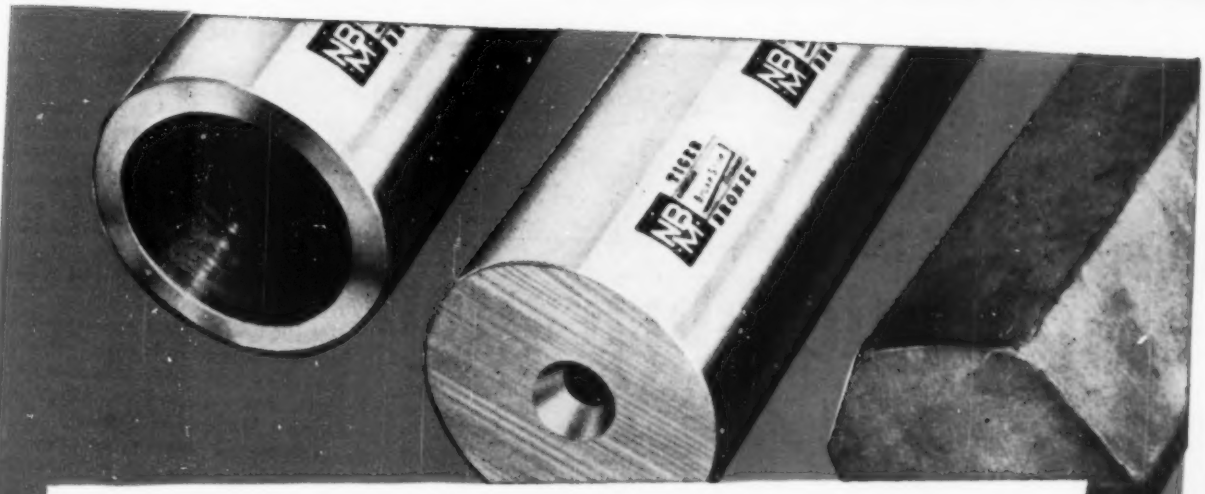

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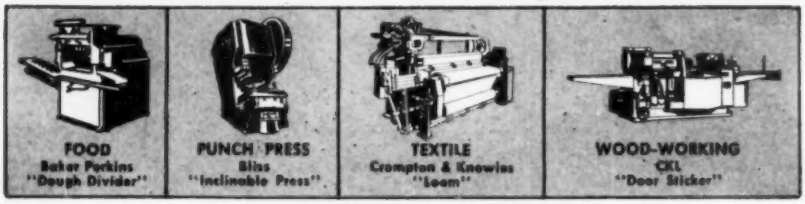
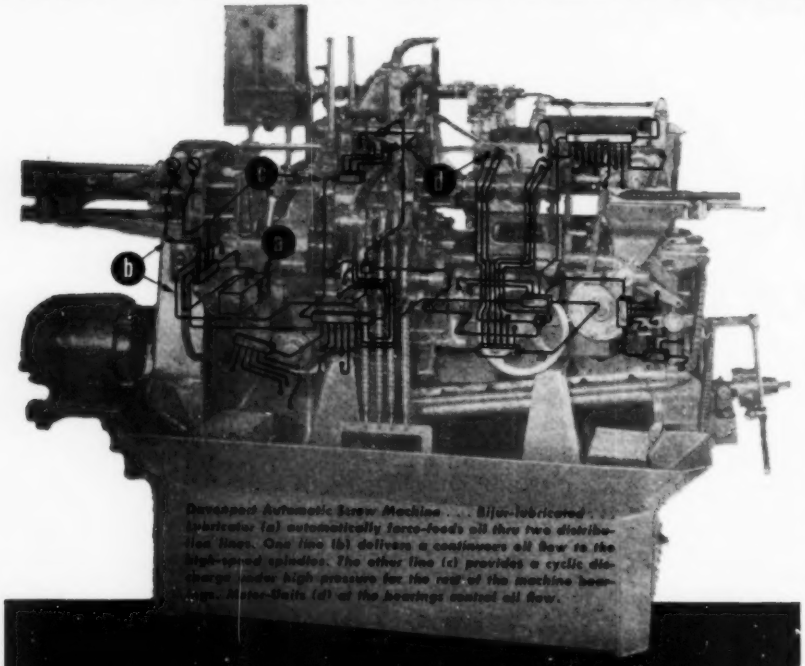


automatic lubrication



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Of special interest are two new charts, one showing graphite flake types in cast iron, and the other illustrating the inclusion content of steel. These charts should help engineers to better understand the metallurgical basis of ferrous alloy selection.

Making Inventions Pay

JOSEPH C. KEELEY, *246 pages, 5½ x 8 in. Published by Whittlesey House, McGraw-Hill Book Co., 330 W. 42nd St., New York 18, N. Y. $2.95.*

This book will give anyone with a spark of creative or inventive ability a practical method of procedure for making his ideas make money.

The author begins with a section on what other inventors have done and includes stories and ancedotes about successful inventions. At the same time, he takes the reader behind the scenes and shows him what most success stories do not tell—the amount of money, time, and effort that go into these inventions before they are made into marketable products. He goes on to show what kind of ideas are practical and what kind are not; how to offer an invention to a manufacturer; how to offer ideas to employers; how to finance a new company; how to produce, advertise and sell a new product; and finally, how to protect an invention.

Algebraic Curves

ROBERT J. WALKER, *Professor of Mathematics, Cornell University 6¼ x 9¼ in., 201 pages. Published by Princeton University Press, Princeton, N. J. $4.*

This book provides an introduction to the new methods in algebraic geometry which have been developed during the past twenty-five years. In much of the published work in this field, the algebraic techniques obscure the underlying geometry. Hence in

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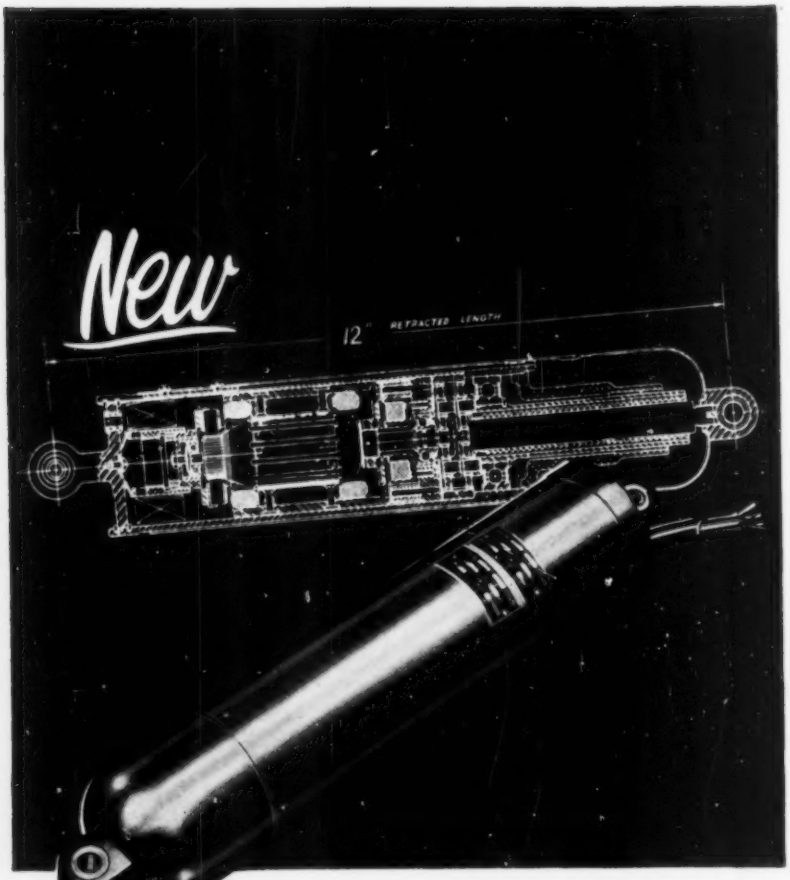

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this book, special effort has been made to emphasize the geometry and to show how classical concepts have been carried over into the new formulation. Thus the book is suitable for anyone beginning algebraic geometry.

Mr. Walker considers only the theory of curves, since here the technical difficulties are few and one can concentrate on the new ideas to be introduced (Generalizations to higher dimensional varieties of the simpler properties of curves are introduced as exercises). The study is carried as far as the theorem of Riemann-Roch, which marks the culmination of the classical theory.

The first two chapters supply a background of those parts of algebra and projective geometry which are needed in algebraic geometry. The remaining four chapters are concerned with the elementary theory of curves, their transformations, and their birational invariants.

Silent Sentinels

Meter Division of Westinghouse, 236 pages, 8½ x 11 in. Published by the Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh 30, Pa. $3.50.

The newly-revised edition of this reference book devoted to protective relays is the first to be issued since 1940. This latest edition records the growth of the relay art to date, including the most recent developments in the design and application of protective relays and relaying systems.

The book is divided into two parts; the first dealing with the application of protective relays, and the second with the equipment itself.

Subdivided into eleven chapters, Part I discusses relays and circuit breakers, faults on power systems, and calculation of short-circuit currents and voltages in the first three chapters. Chapters 4 through 7 deal with vectors for relay systems, protection of a-c apparatus, protection of station busses, and protection of transmission circuits. The remaining chapters of Part I treat pilot relaying by wire and carrier, protection of multi-terminal lines, d-c system protection, and miscellaneous relay applications.

Part 2, consisting of eight chapters, presents detailed descriptions of the various types of Westinghouse protective relays. The construction and operation of each type is explained, and its characteristics thoroughly discussed.

The entire book is well illustrated with circuit and vector diagrams, photographs and curves. A 21-page appendix includes tables of characteristics for various types of relays.